THE SCIENTIFIC MONTHLY

THE SCIENTIFIC MONTHLY

EDITED BY J. McKEEN CATTELL

VOLUME XXVIII
JANUARY TO JUNE

NEW YORK
THE SCIENCE PRESS
1929

THE SCIENCE PRESS PRINTING COMPANY
LANCASTER, PA.

THE SCIENTIFIC MONTHLY

JANUARY, 1929

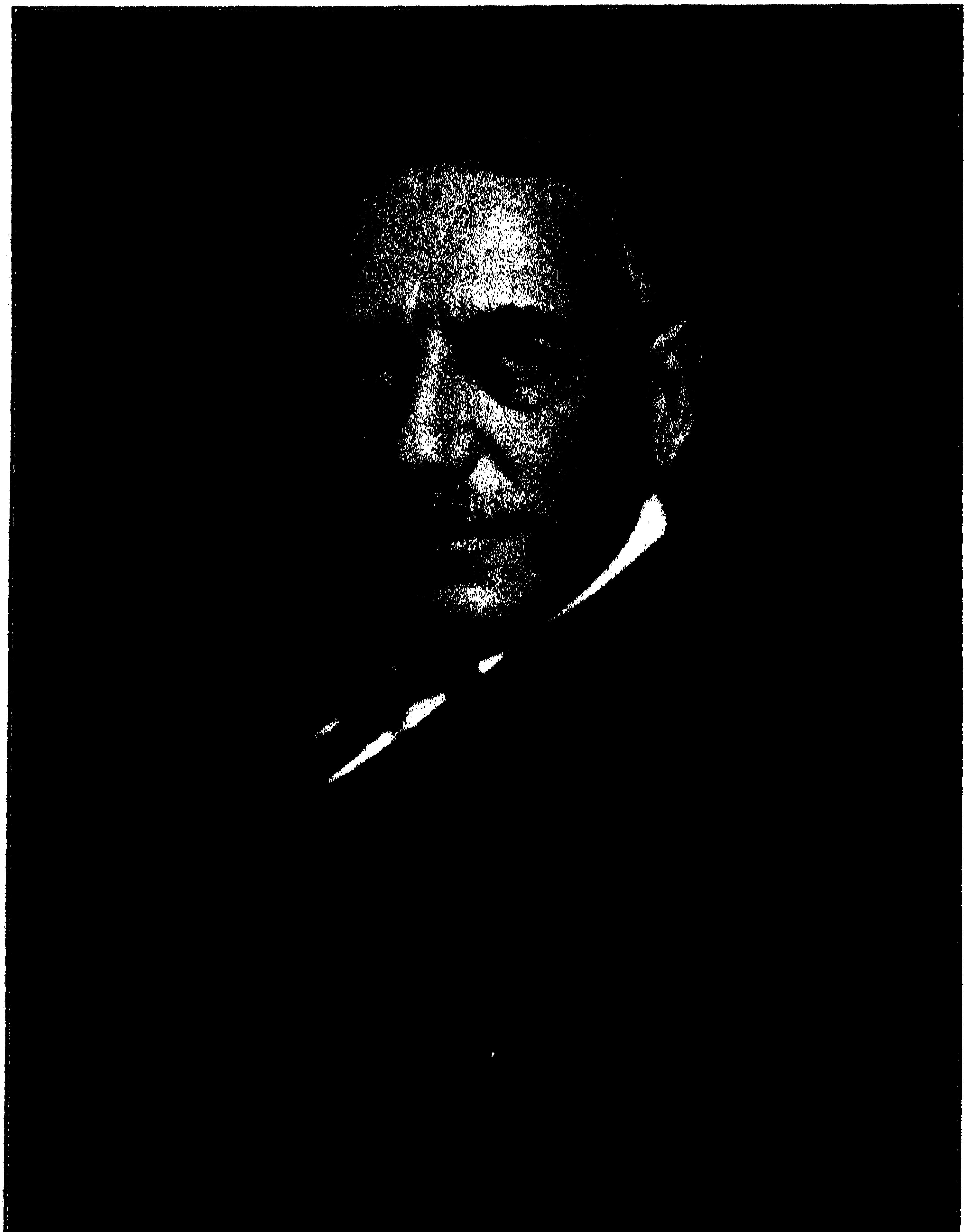
THE NEW YORK MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

By Dr. HENRY FAIRFIELD OSBORN[1]
PRESIDENT OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

On behalf of the fifty educational and scientific organizations of New York City, I extend a cordial welcome to the members of the American Association for the Advancement of Science and of the associated scientific societies. The national and local committees have agreed on a seven-day program, which will begin with Professor Bailey Willis's address on "Continental Genesis" on Wednesday, December 26, and will close on the evening of Tuesday, January 1, with Professor Harlow Shapley's address on "Galaxies of Galaxies." The intervening days and evenings will be chiefly devoted to topics in geology, physics, biology, chemistry and anthropology in the order named. Each address will be accompanied by an evening reception in the corresponding department of the American Museum of Natural History. Following the admirable precedent set by the British Association, these evening addresses will be of a semi-popular character destined to attract and stimulate the rapidly growing interest in science manifested in the city of New York and throughout the United States and Canada. The leading motif of this science week program, however, is to offset some of the extreme specialization of the present day by a more general prospectus of the unity and harmony of various sciences such as prevailed in the unified spirit of the great founders of the association eighty-five years ago. Special honor should be done on December 27 to Louis Agassiz on this centenary of his epoch-making glacial theory.

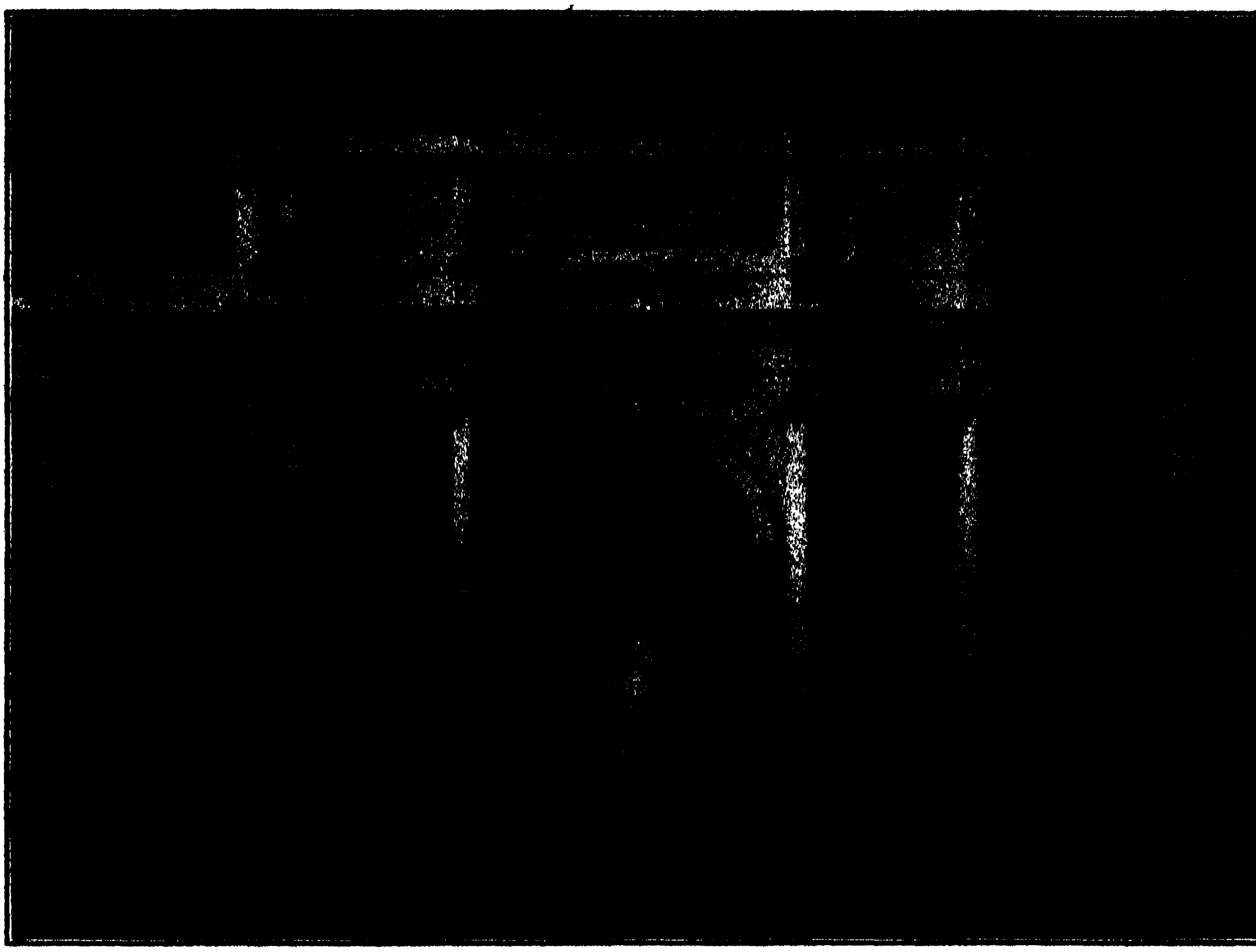
Visiting scientists will be impressed with the really marvelous developments to be witnessed in the fifty institutions which are extending their hospitality, the large majority of which were unknown and unthought of in the year 1888, when President Seth Low was called to be the head of Columbia University, and President Eliot, of Harvard University, delivered the leading inaugural address, in which he commented with some sarcasm on the violent contrast between the material wealth and affluence of the city of New York and the poverty and backwardness of its scientific, educational and literary spirit. A complete not only metamorphosis but metapsychosis has taken place since that only too truthful inaugural address of President Eliot, for New York has become one of the leading scientific and

[1] Assisted by Helen Ann Warren, assistant local secretary. Prepared at the general headquarters of the American Association for the Advancement of Science, Education Hall, American Museum of Natural History, 77th Street and Central Park West, New York City.



DR. HENRY FAIRFIELD OSBORN

PRESIDENT OF THE AMERICAN MUSEUM OF NATURAL HISTORY AND RESEARCH PROFESSOR OF ZOOLOGY, COLUMBIA UNIVERSITY. DR. OSBORN IS PRESIDENT OF THE AMERICAN ASSOCIATION.



—*From the American Museum of Natural History*

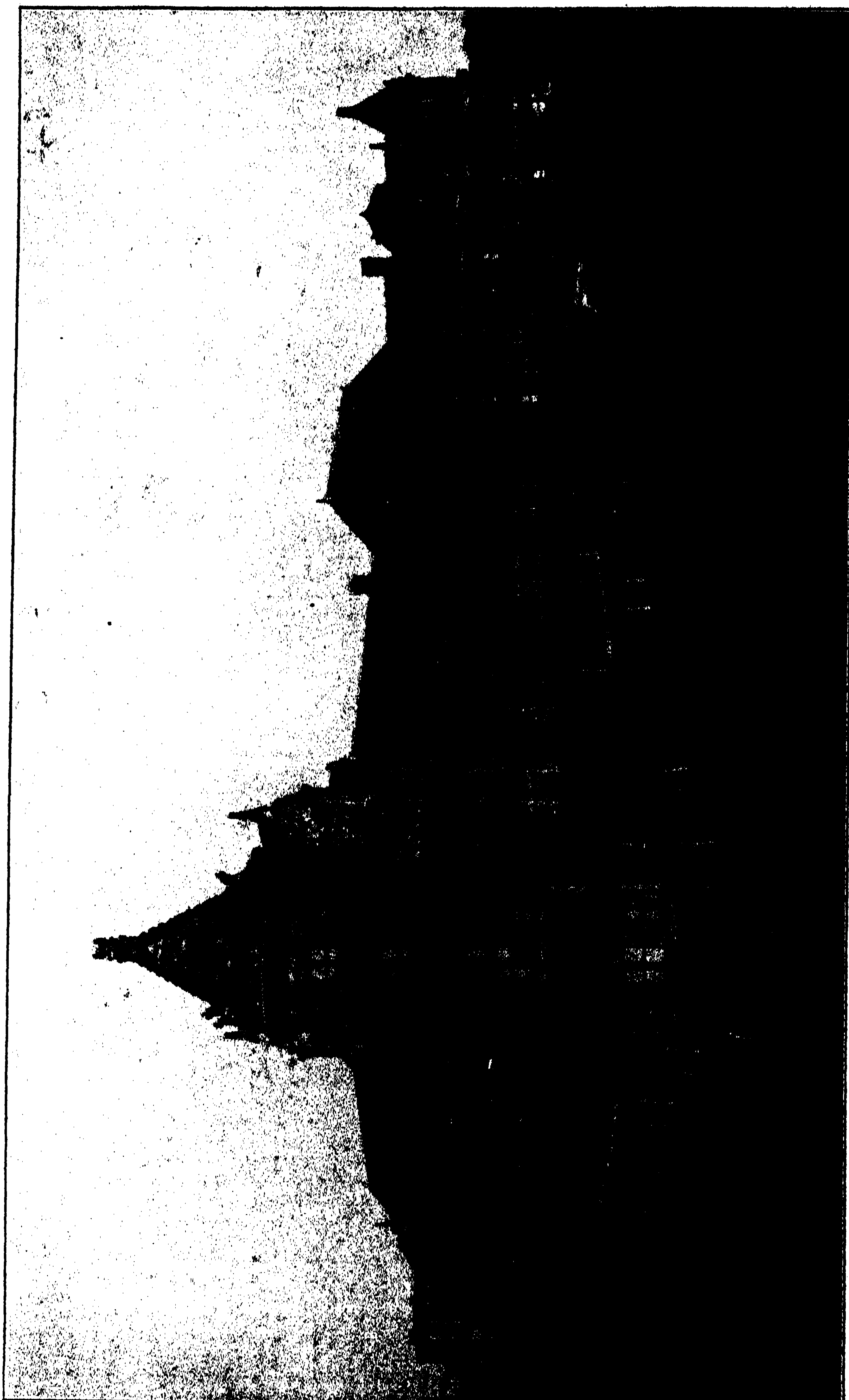
DARWIN HALL
THE AMERICAN MUSEUM OF NATURAL HISTORY.

educational centers of the world. It has attracted leading workers not only from the United States to its institutions of pure and applied science but from great centers of learning and research abroad. From being purely metropolitan it has become truly cosmopolitan.

During the past twenty-eight years the local government of the city of New York has led all cities of the world in building up great institutions of art, science and literature, so that by a few giant strides New York has overtaken and in some instances has surpassed the work of centers of learning in the great capitals of Europe. A delightful feature of Science Week will be the Sunday evening reception at the splendid Metropolitan Museum of Art by the mayor of the city and the trustees of the museum. Another is the Sunday afternoon Philharmonic-Symphony concert, led by the famous conductor, Mengelberg, and donated especially to the visiting members of the association through the generosity of Mr. Clarence H. Mackay, president of the Postal Telegraph-Cable Company. On Sunday morning leading preachers in thirty-eight pulpits of all denominations have been invited by the president to address the public and visitors to New York during this great science week on the subject "Nature and Religion."

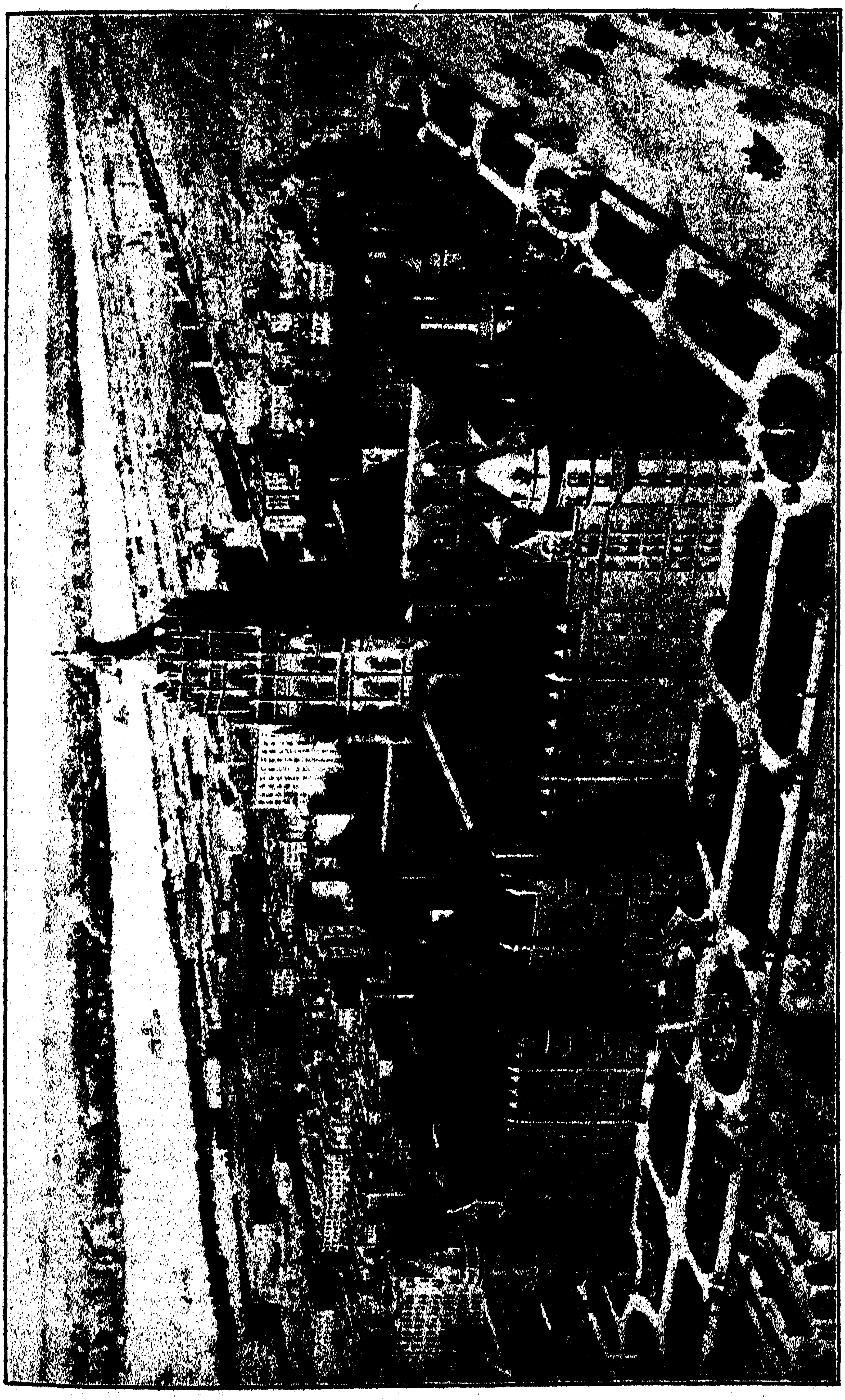
NEW YORK CITY WELCOMES THE ASSOCIATION

New York City welcomes the American Association for the Advancement of Science for the fifth time. Fifty scientific and educational institutions, many of them newly housed in splendid buildings, others still the familiar landmarks of past meetings, except for innovations in equipment, await the inspection of their out-of-town guests.



THE AMERICAN MUSEUM OF NATURAL HISTORY

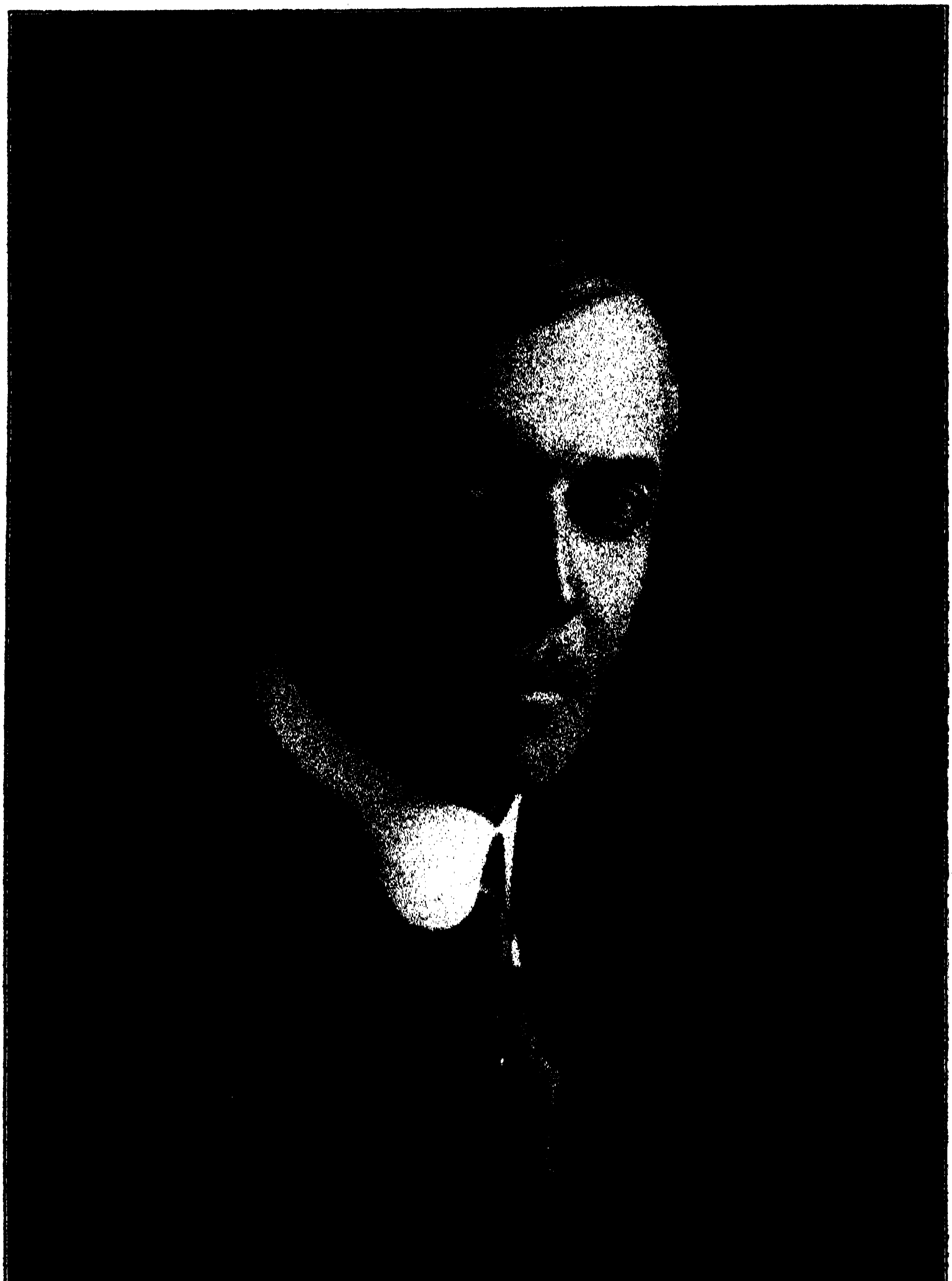
—*From the American Museum of Natural History*



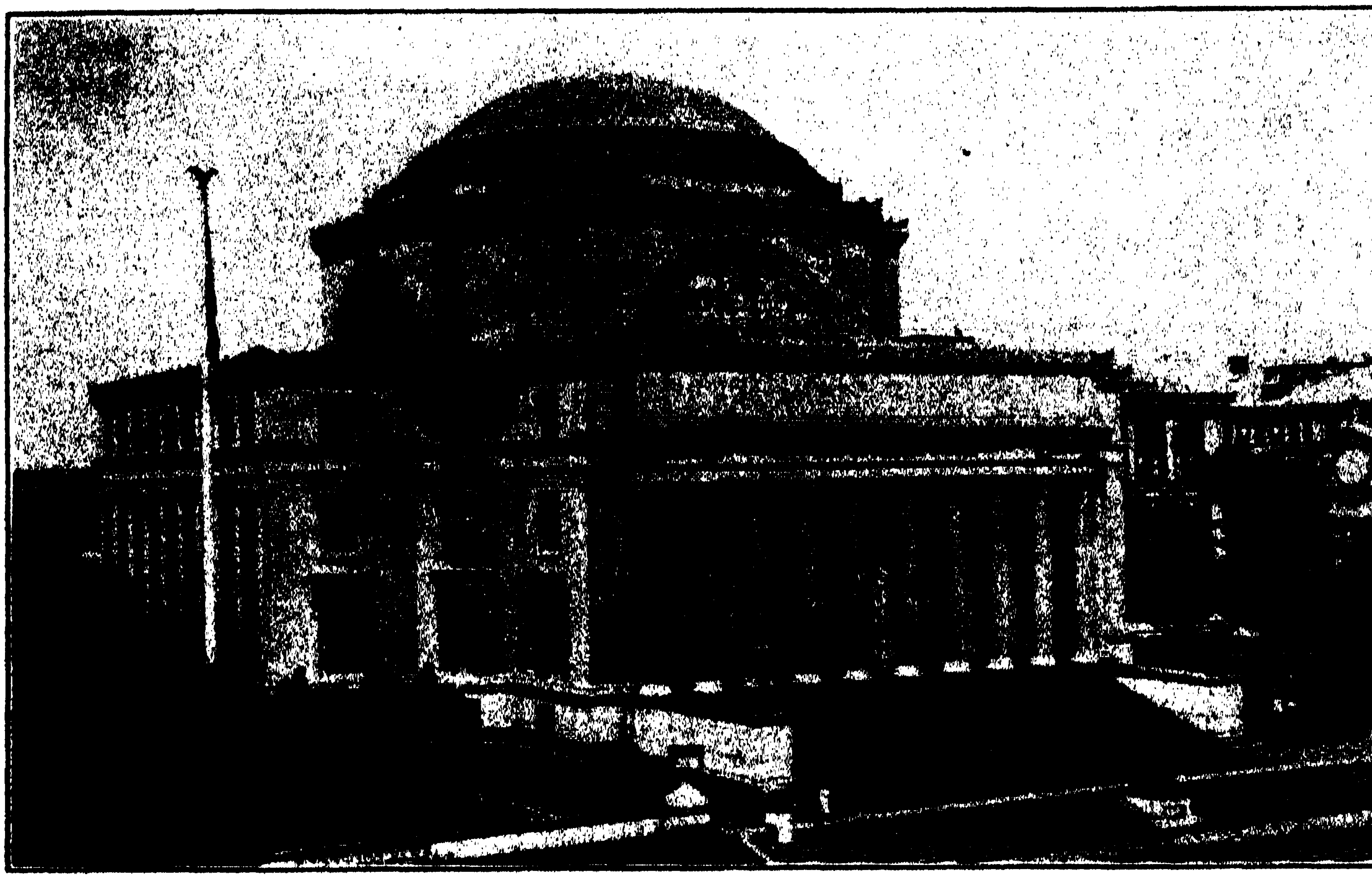
—*From the American Museum of Natural History*

THE COMPLETED AMERICAN MUSEUM OF NATURAL HISTORY

AS DESIGNED BY THE ARCHITECT IN 1891



DR. ARTHUR A. NOYES
DIRECTOR OF THE GATES CHEMICAL LABORATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY.
DR. NOYES IS THE RETIRING PRESIDENT OF THE AMERICAN ASSOCIATION.

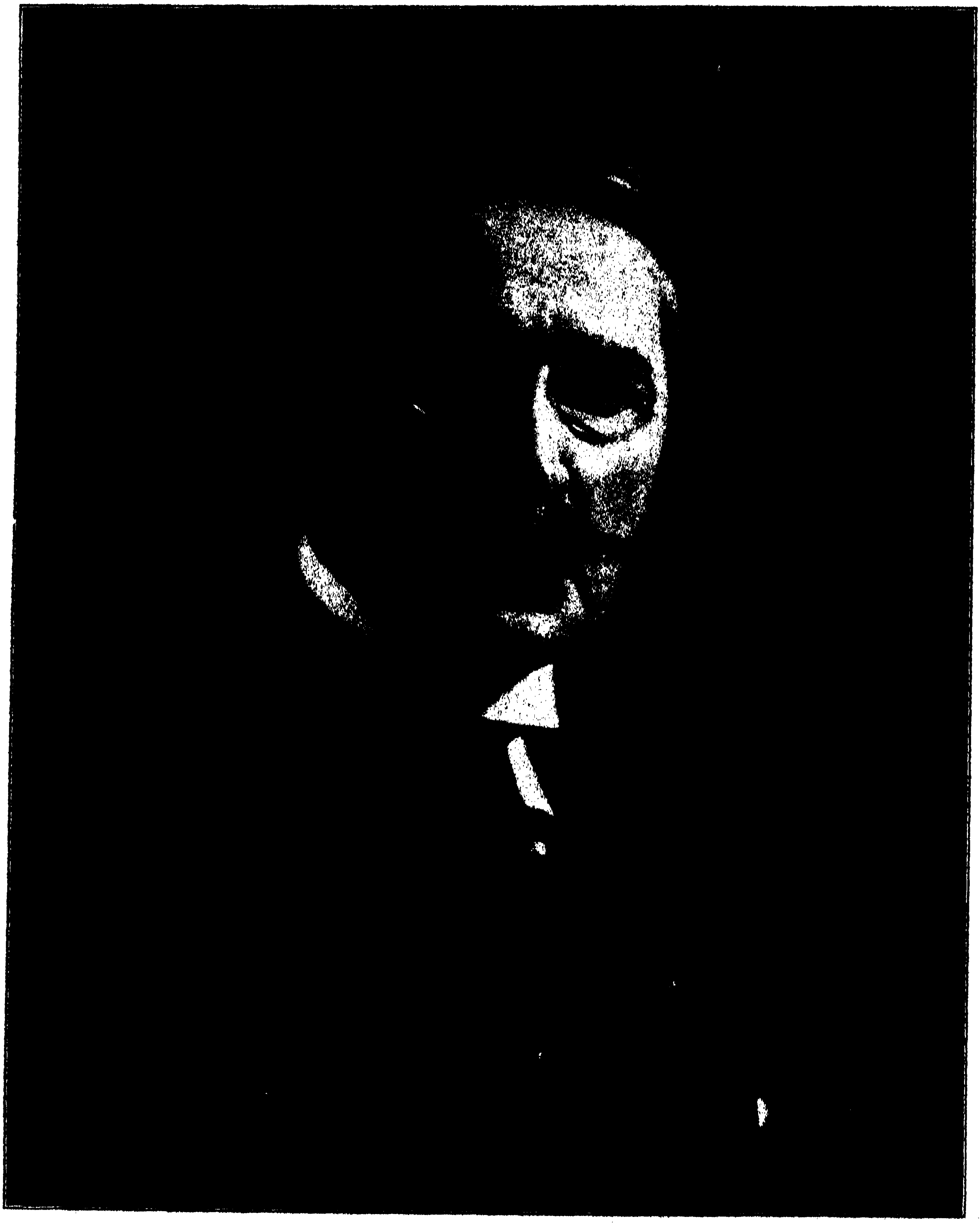


THE LIBRARY OF COLUMBIA UNIVERSITY

The schools, universities, museums and laboratories of a nation represent its intellectual vigor as cultivated by just such organizations as the American Association and by the individuals who compose its membership. New York City because of its size and prosperity is the location of a fair share of these institutions of the United States. In fact, members who remember the brownstone city during the sultry August meeting of 1887, when S. P. Langley was president, and those who rode around the growing city of 1900 in horse-cars to hear President R. S. Woodward and his contemporaries, as well as the elevated travelers of December, 1906, who listened to President William H. Welch, and the subway straphangers of December, 1916, when Charles R. Van Hise was president, will be amazed at the city's growth in scientific institutions as well as in scientific and commercial skyscrapers. Notable among the newer skyscrapers, for instance, is the medical center of Columbia University and the Presbyterian Hospital, located at 168th Street and Broadway on a hilltop and commanding the Hudson River for miles up and down stream.

There have been many changes on the Columbia University campus in the twelve years since the association last met there. Among these the Physics Building, the Chemistry Building, School of Business, Barnard Hall and the recently completed Teachers College halls offer the latest sort of university and laboratory equipment.

At the American Museum, where all the evening general sessions will be held, a greatly increased collection of animal and mineral specimens, arranged in strikingly effective natural habitat groups, invite examination. During the past twelve years the museum authorities have worked out the wall alcove display method with some really beautiful results. Crowds of interested children in the Indian, mammal, fish and bird halls testify to the real value of the natural background method, while their



DR. MICHAEL I. PUPIN

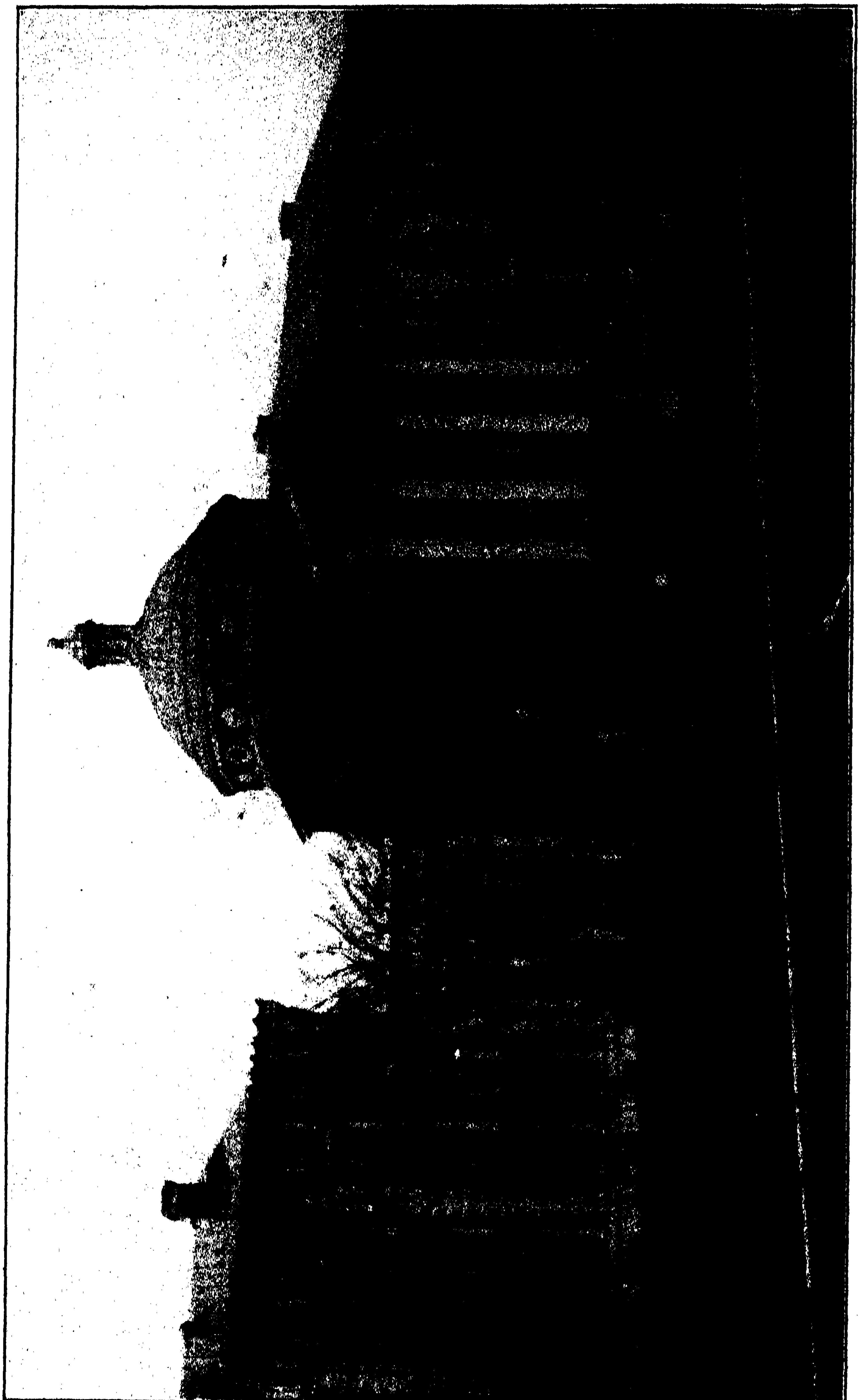
PROFESSOR OF ELECTROMECHANICS, COLUMBIA UNIVERSITY. DR. PUPIN IS HONORARY CHAIRMAN OF THE LOCAL COMMITTEE AND WAS PRESIDENT OF THE AMERICAN ASSOCIATION IN 1925.

THE NEW PHYSICS BUILDING OF COLUMBIA UNIVERSITY

elders find food for speculation in the Hall of the Age of Man, the comparative anatomy exhibits, the recently enlarged Dinosaur and Reptile Halls, the Darwin Hall, the Forestry and Oceanic Halls, the Geological, Astronomical and Anthropological exhibits and the Hall of Jewels. Color and form are vital elements in nature and in the art which simulates nature. These have been particularly studied at the American Museum of late years through the inspiration of Carl Akeley and his friends until the business of taxidermy has added the art of painting and sculpture to its model mounting and has become a living merger of art and science.

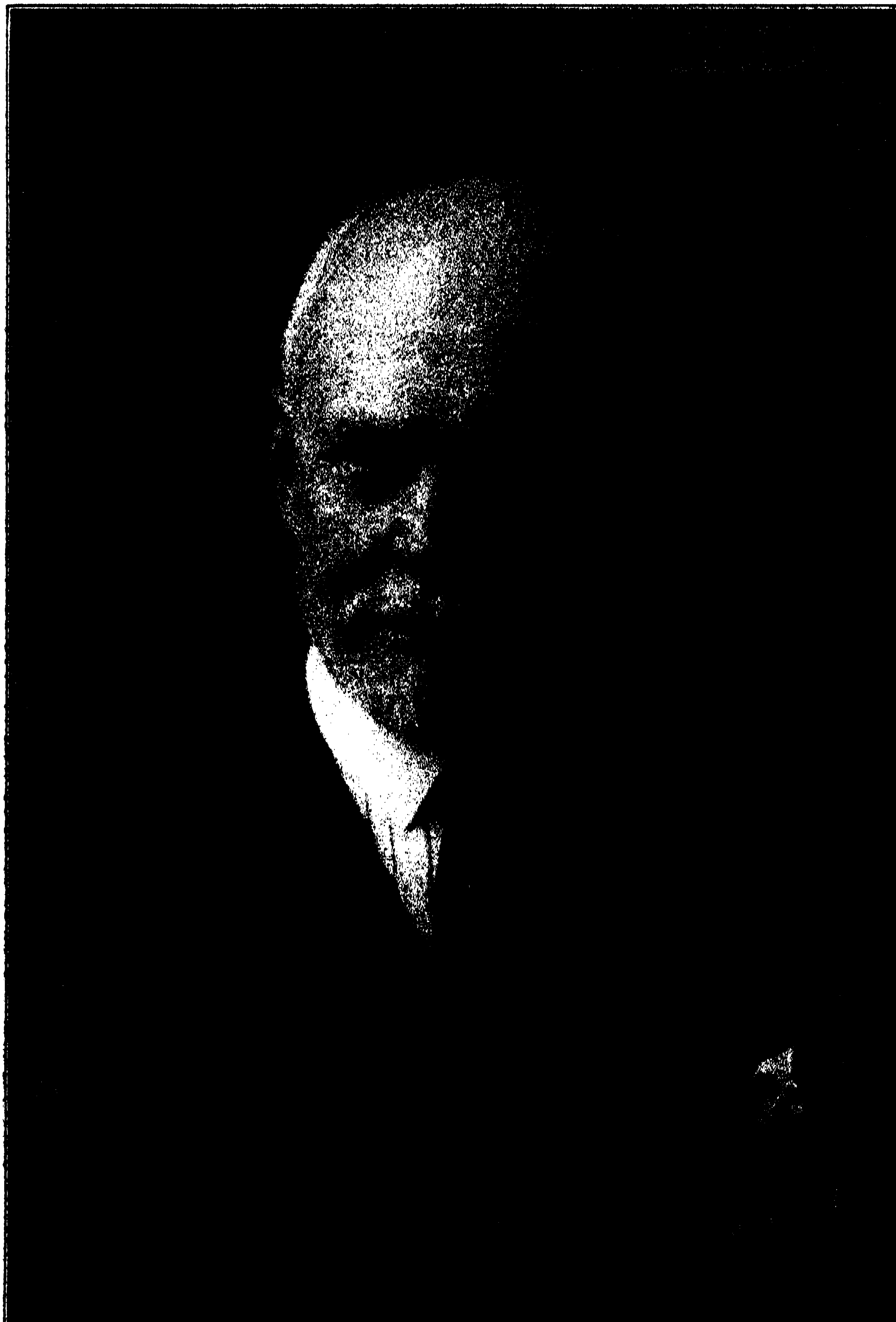
Beside the meetings at Columbia and the American Museum some of the sessions of the association and its associated societies will take place at the United Engineering Societies Building on West 40th Street. One or two will occur at the New York Academy of Medicine's quarters at 103rd Street and Fifth Avenue, while there will also be hotel meetings and various excursions. Photographs of some of the places to be visited accompany this article.

Among the institutions acting as hosts to the visiting scientists are: The American Chemical Society, The American Geographic Society, The American Institute of Electrical Engineers, The American Institute of Mining and Metallurgical Engineers, The American Museum



BUILDINGS OF COLUMBIA UNIVERSITY

EARL HALL, IN THE CENTER, WITH THE BUILDINGS FOR MINING AND ENGINEERING. BARNARD COLLEGE IS IN THE BACKGROUND.



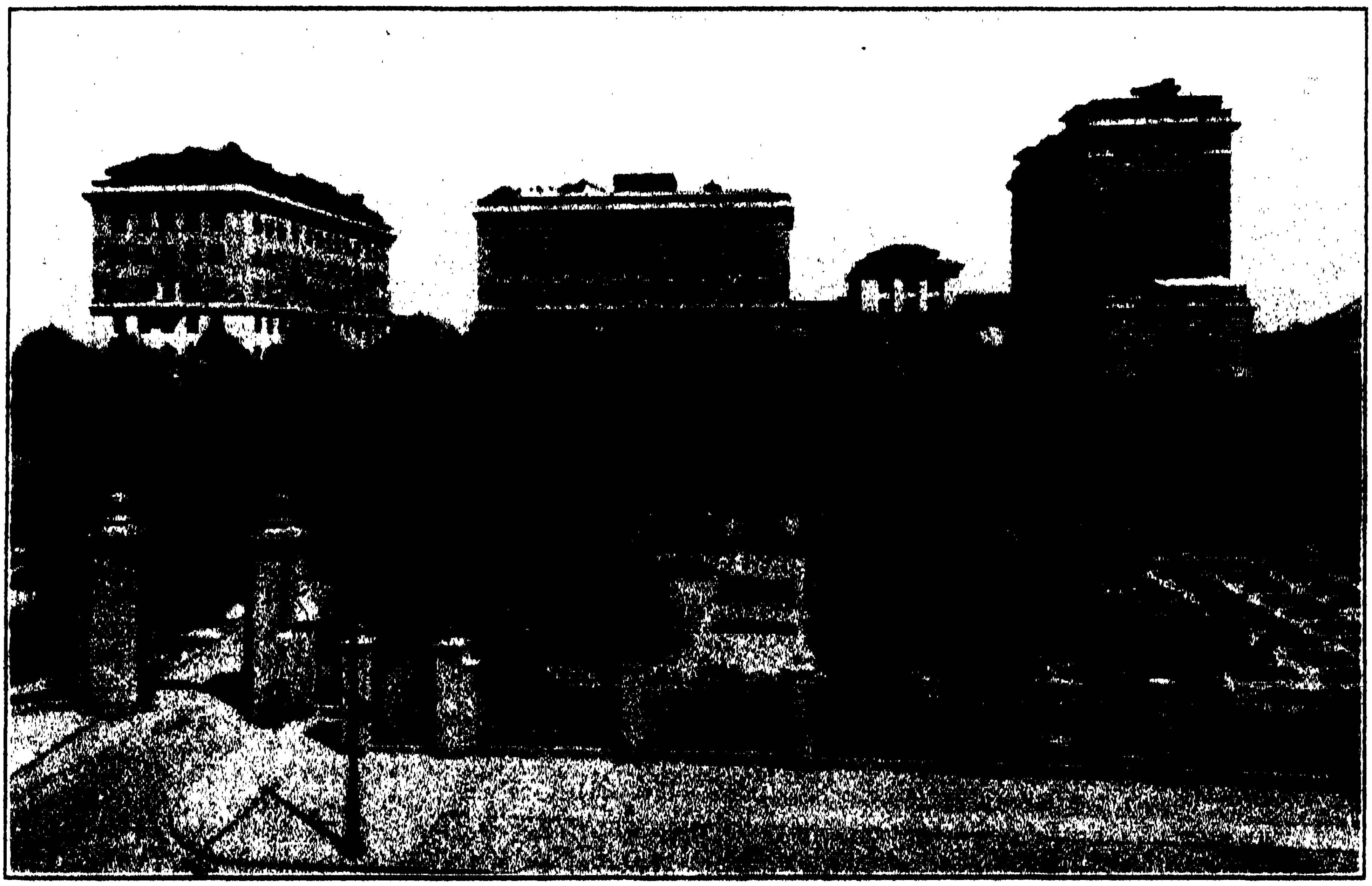
DR. E. B. WILSON

Emeritus professor of zoology, Columbia University. Dr. Wilson was president of the American Association in 1914.

—*Underwood & Underwood*

THE MEDICAL CENTER OF COLUMBIA UNIVERSITY

FORMALLY DEDICATED TO RESEARCH, TEACHING AND CARE OF THE SICK, ON OCTOBER 12, 1928.



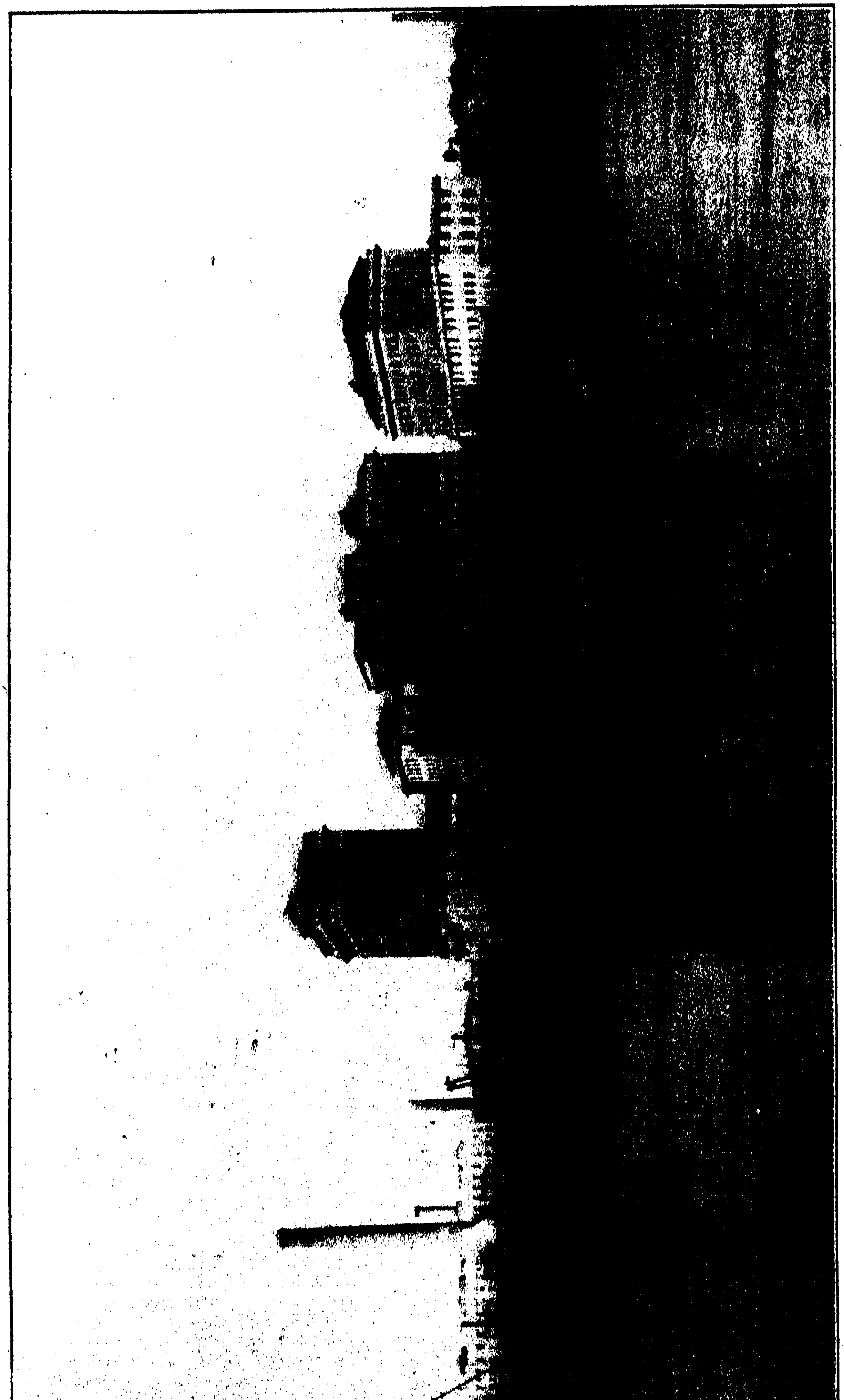
THE ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH

of Natural History, The American Society of Civil Engineers, The American Society of Mechanical Engineers, The American Telephone and Telegraph Company and the Aquarium.

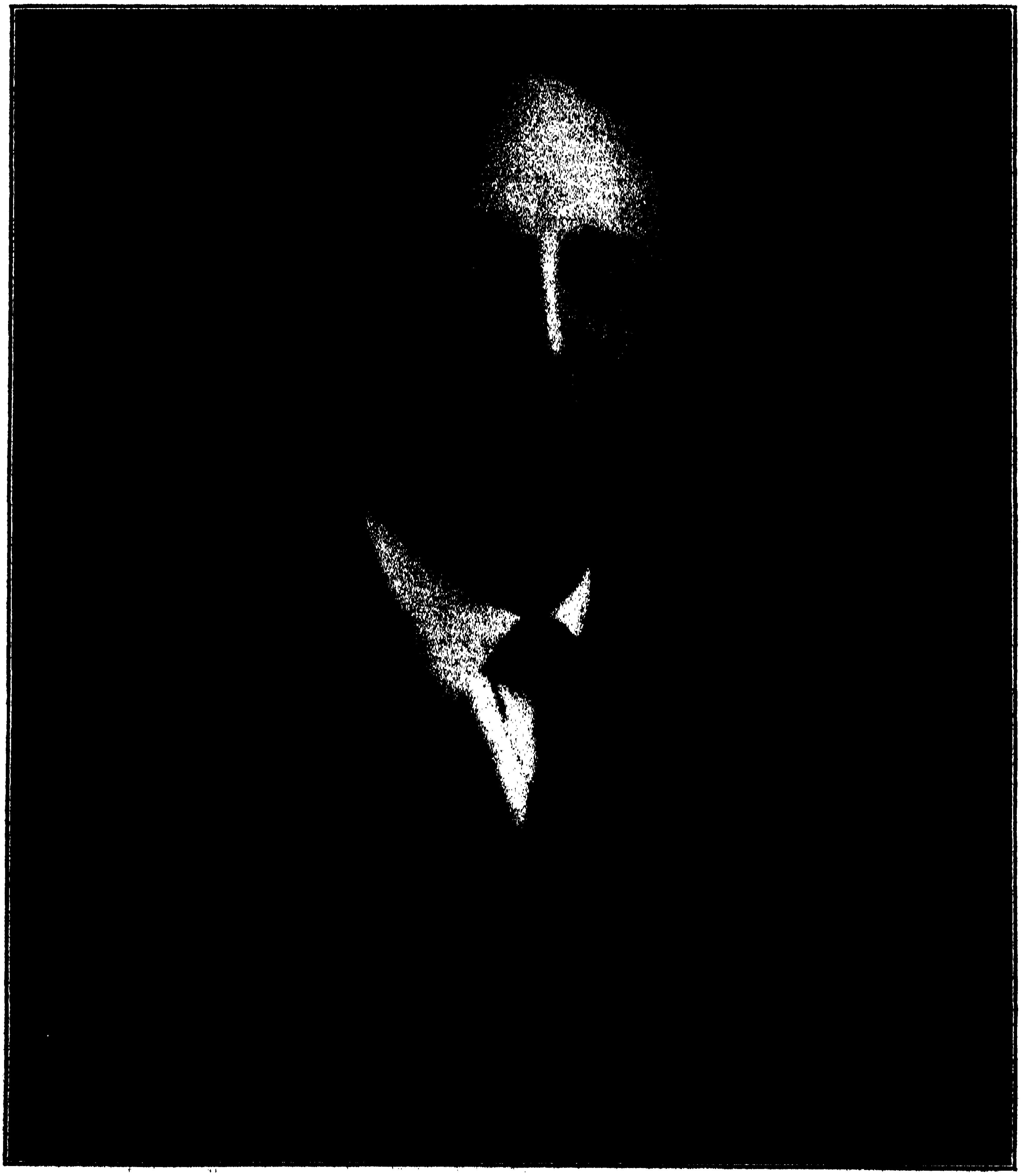
Barnard College, The Biological Laboratory of the Long Island Biological Association, The Brooklyn Botanic Garden, The Brooklyn Institute of Arts and Sciences, The Casa Italiana of Columbia University, The Chamber of Commerce of the State of New York, The Chemical Foundation, The College of the City of New York, The College of Physicians and Surgeons, Columbia University, Cooper Union for the Advancement of Arts and Sciences and Cornell University Medical College.

The Engineering Foundation, The Eugenics Record Office of the Carnegie Institution of Washington, Fordham University, The General Electric Company, The Hispanic Society of America, The Horace Mann School, The Hotel Association of New York, The International Education Board, The International House, The Lincoln School, The Long Island College Hospital, The Merchants Association of New York, The Metropolitan Museum of Art, The Museum of the American Indian, The Museum of the State of New York and the Museums of the Peaceful Arts.

The New York Academy of Medicine, The New York Academy of Sciences, The New York Botanical Garden, The New York Department of Health, The New York Historical Society, The New York Post-Graduate Medical School and Hospital, The New York Telephone Company, New York University, The New York Zoological Society, the Postal Telegraph-Cable Company, The Radio Corporation of America, The Rockefeller Institute for Medical Research, The Russell Sage Foundation, The Station of Experimental Evolution of the Carnegie Institution of Washington, Stevens Institute of Technology, Teachers College, The University of the State of New York, the Western Electric Company and The Western Union Telegraph Company.



THE ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH



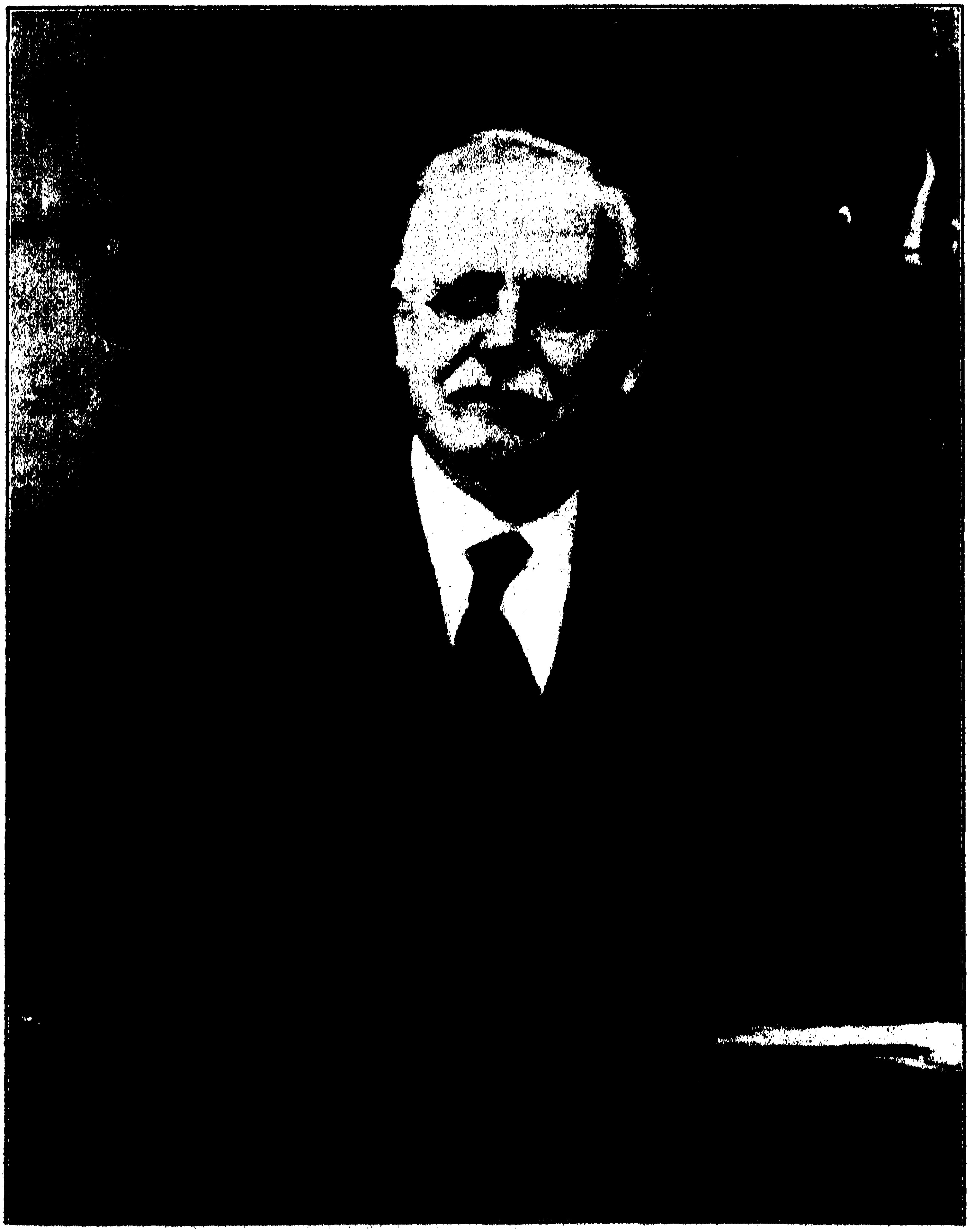
DR. SIMON FLEXNER
DIRECTOR OF THE LABORATORIES, THE ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH.
DR. FLEXNER WAS PRESIDENT OF THE AMERICAN ASSOCIATION IN 1920.

THE BOYCE-THOMPSON INSTITUTE FOR PLANT RESEARCH

Excursions, mentioned above, will visit the Aquarium, where the strangest fish in the world and the most common food fish swim peacefully in the walls which once echoed to Jenny Lind's sweetest notes. The most recent acquirements at the Aquarium come from the Galapagos Islands and are quite extraordinary. The Zoo, with its realistic jungle and Arctic backgrounds, will be visited, as will be the greenhouses of the New York and Brooklyn Botanic Gardens, the Children's Museum of Brooklyn and the Western Electric Laboratory.

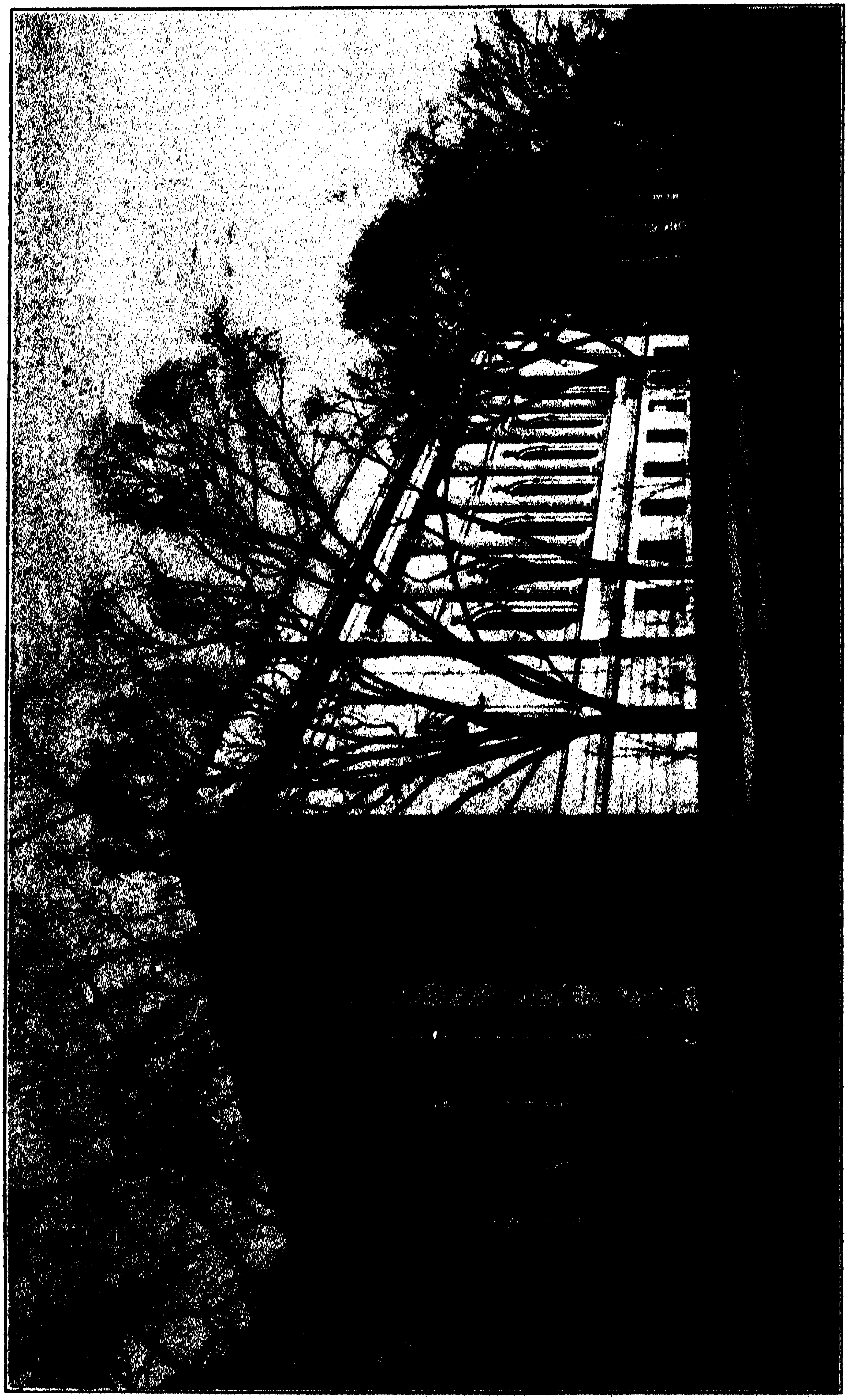
Besides these scientific excursions there remain the old-time haunts of Peter Stuyvesant's, Alexander Hamilton's and Grover Cleveland's city, Fraunce's Tavern, Trinity Church, St. Paul's Chapel, Battery Park, the Jumel Mansion, where Aaron Burr lived, the Gracie Mansion, the Dyckman farmhouse and Grant's tomb. There is the bustling port of New York to watch; the rambunctious Stock Exchange; the East Side city of immigrant Jews, Armenians, Italians; the Russian quarter; Greenwich Village; the German midtown blocks of the East Side; the fashionable city; the coffee district, silk district, paper district, toy district, department store district; and Broadway, where opera, tragedy, farce, vitaphone, movietone and the flea circus elbow each other for ten crowded blocks. There is the alarming new Paramount Building to marvel at, the peaceful paths of Central Park for a brisk walk and the impressive American Wing of the Metropolitan Museum of Art, where American history unfolds itself through the hospitality of American homes. An old visitor to New York will never tire of crossing Brooklyn Bridge afoot at sunset, nor regret a visit to the top of the Woolworth Tower to view a skyline that has changed vastly in the last three years.

There are all these places and more to see in the city that is for the moment completed. Then there is the city under construction. Here rises the Cathedral of St. John the Divine, building on the medieval plan and containing an already famous sports window, where the everyday college football player, crewman, polo player and hurdler stand perpetuated in Cathedral glass. Westward the Hudson River suspension bridge rears its great skeleton on the New York and Jersey shores, though the intervening span is still imaginary. Eastward the Eighth Avenue subway continues to get

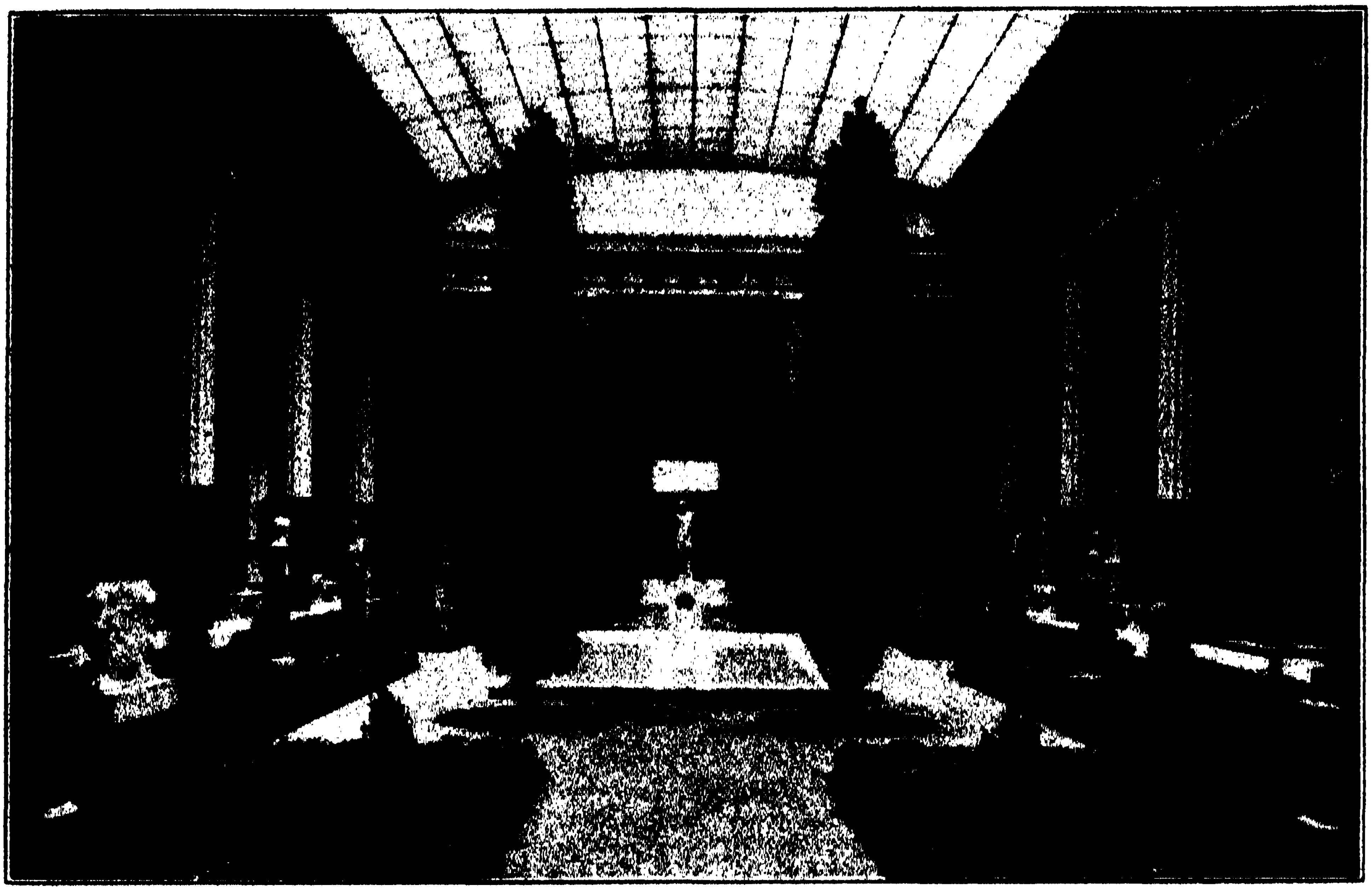


DR. JOHN M. COULTER

THE BOYCE-THOMPSON INSTITUTE. DR. COULTER WAS PROFESSOR OF BOTANY FROM 1896–1925 AND WAS PRESIDENT OF THE AMERICAN ASSOCIATION IN 1919.



THE METROPOLITAN MUSEUM OF ART



THE ROMAN COURT
METROPOLITAN MUSEUM OF ART.

itself built while the city marches atop its excavations. All about the town the amusing spectacle of building from the top down goes on while the crowds hurry to work happy because it is Christmas and high-spirited because the air is crisp and so much is going on.

American Association Program

A great deal will be going on for the American Association. The association meets this year with the largest enrolment in its history. Its more than 17,000 members represent every state in the Union and all parts of the Dominion of Canada. Every field of science from the broadest aspects to the most minute and detailed sort of investigation has its place on the program, while general sessions have been planned to synchronize the whole, to bring back some measure of the advantages of the old-fashioned all-around scientist over his necessarily specialized successor, and to give each worker a glimpse of all science: in its relation to his work, in its value as a method of thought and in its extreme importance to the daily problems of civilization.

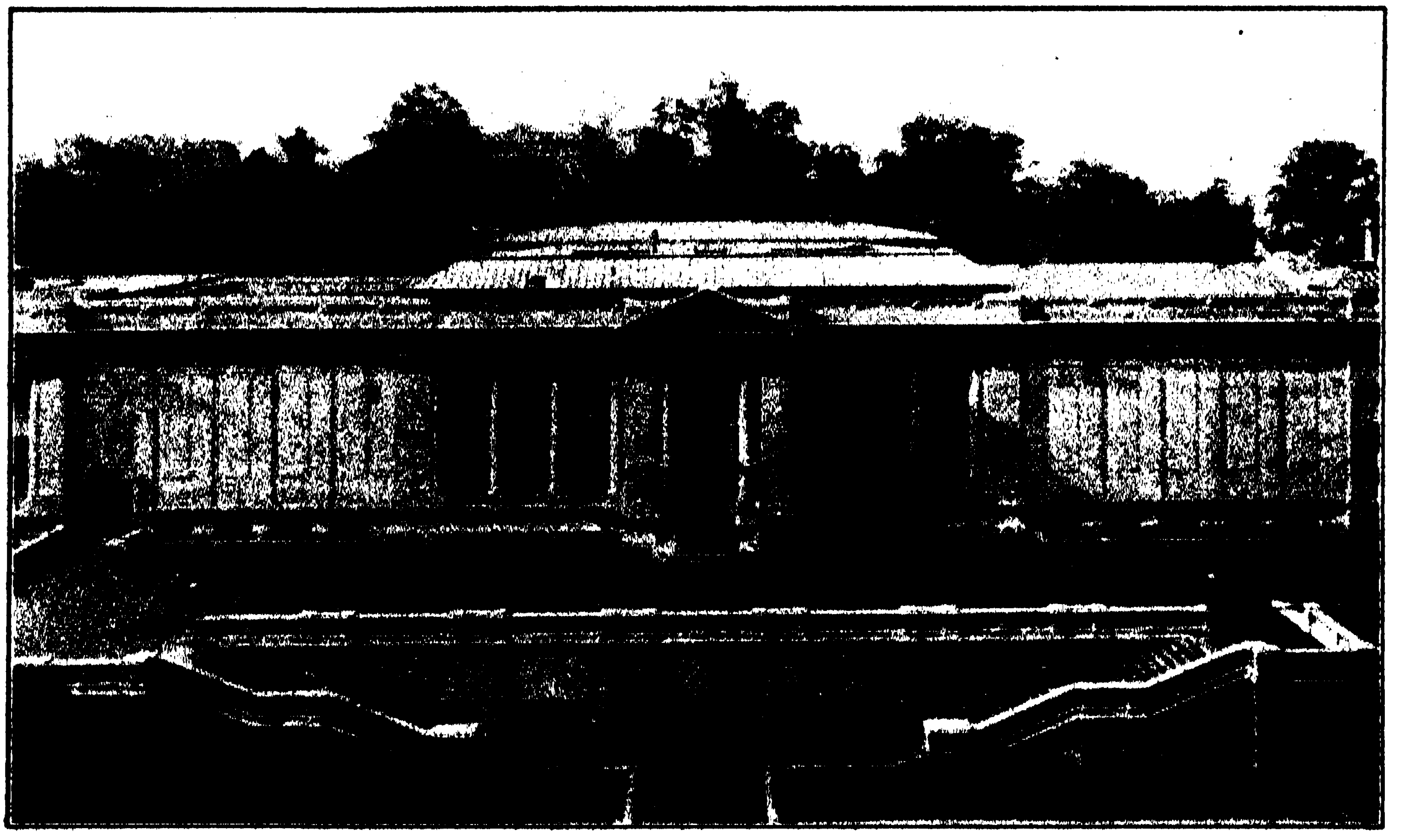
The president, in the midst of his extreme occupation with the pressing daily affairs of his great museum and his extensive researches, has given a great deal of time and consideration to this general program and has arranged that every branch of scientific endeavor will have its special open session for non-technical addresses. These will occur unless otherwise noted in the auditorium of the American Museum of Natural History and will be followed by an informal reception in Education Hall and an inspection of the exhibition halls closely related to the subject under discussion.

The program of general sessions is as follows:

Thursday, December 27, 1928

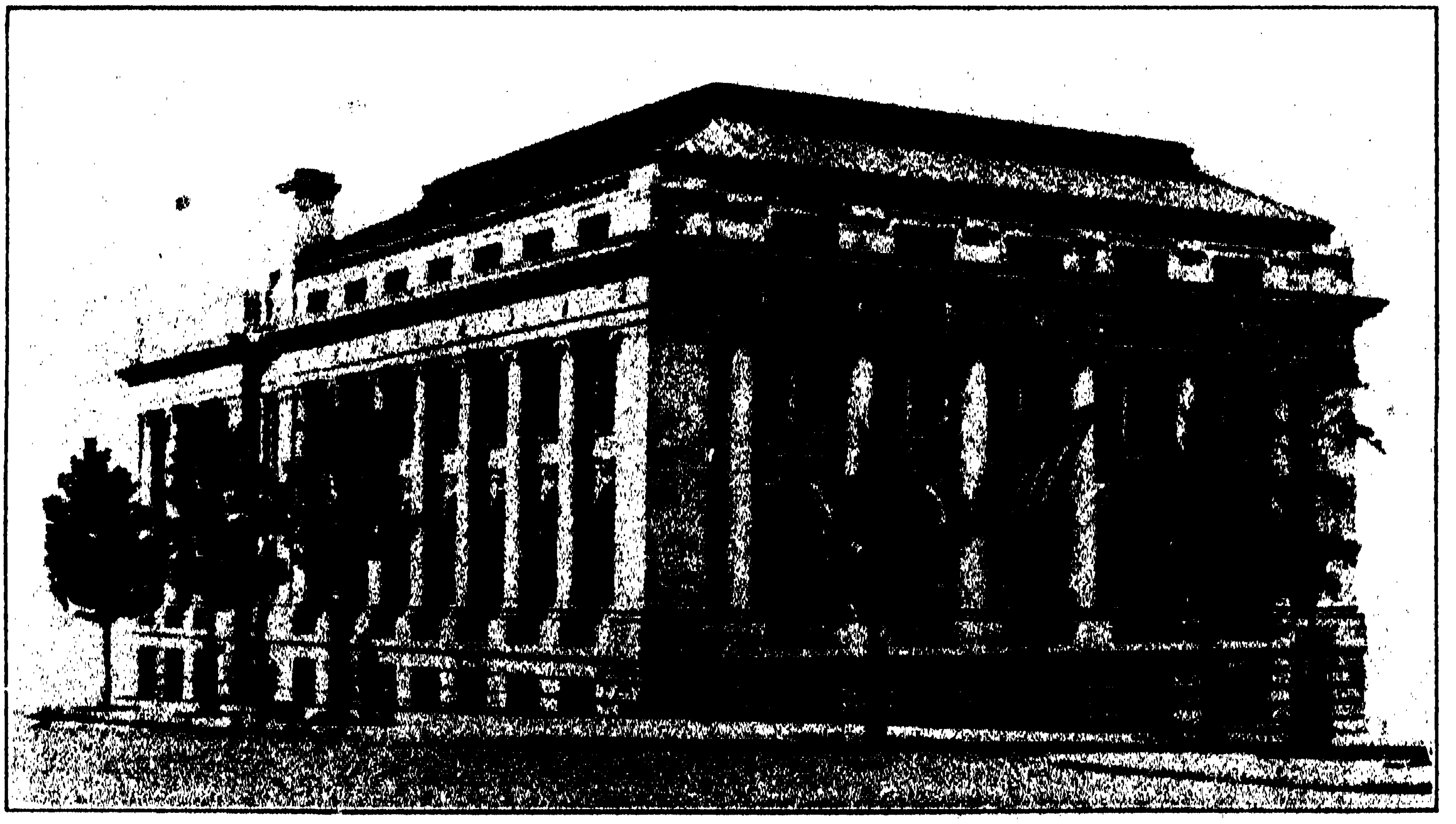
Afternoon

Geologic Symposium, "The Centenary of the Glacial Theory." Addresses by Drs. Osborn

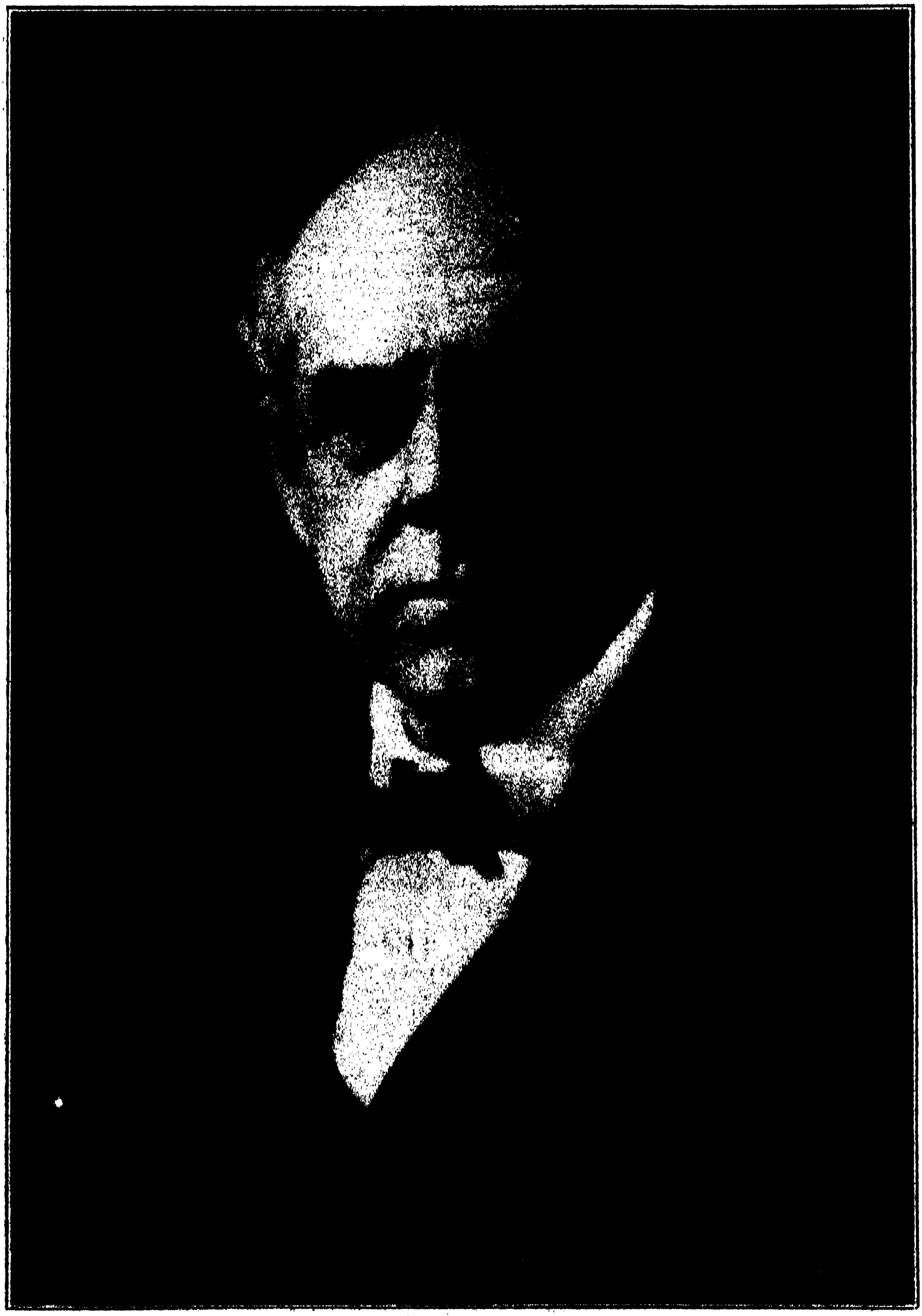


—*Hispanic Society of America*

THE BUILDING OF THE HISPANIC SOCIETY OF AMERICA

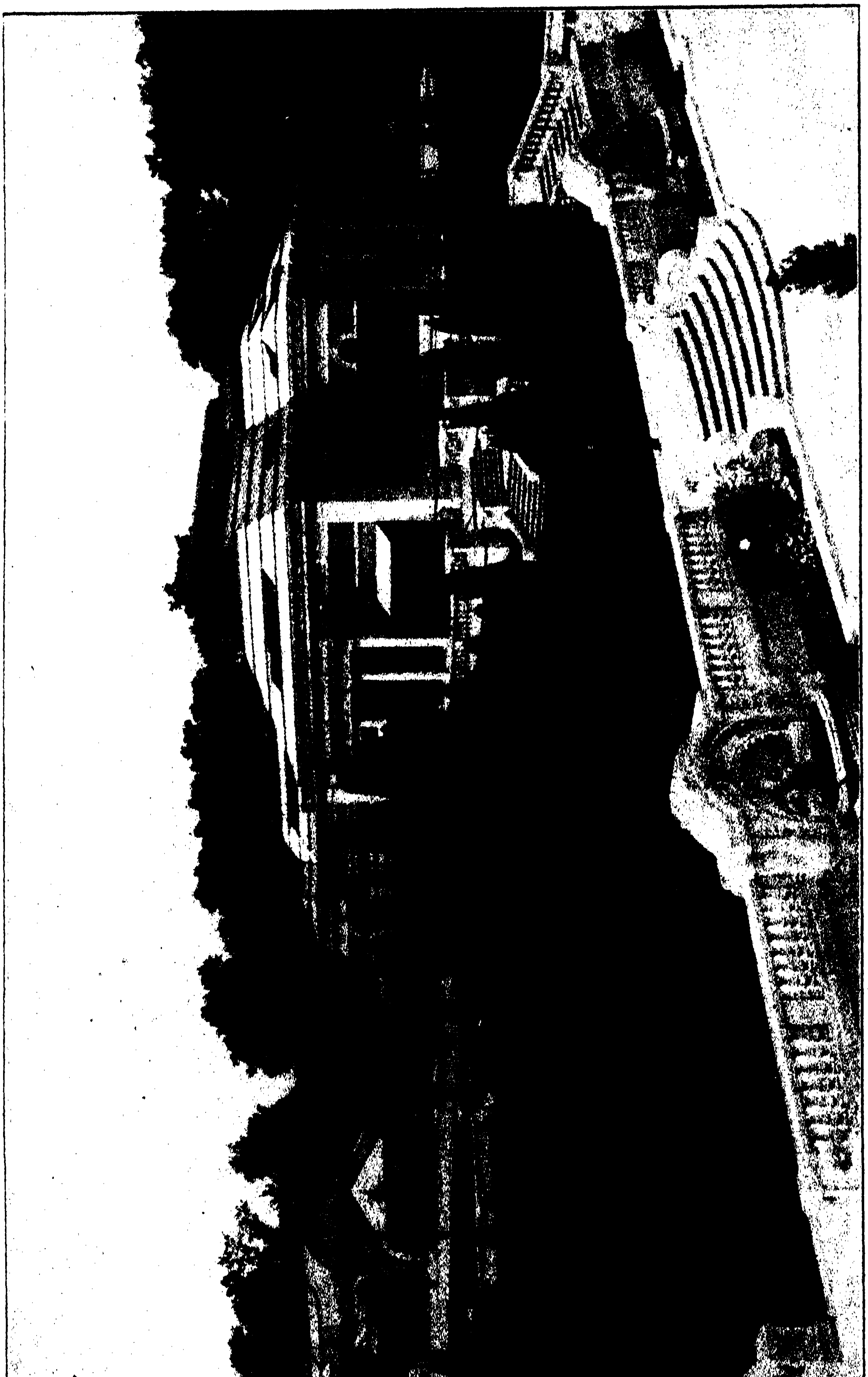


THE MUSEUM OF THE AMERICAN INDIAN
HEYE FOUNDATION.



DR. J. McKEEN CATTELL

EDITOR OF *Science* AND THE SCIENTIFIC MONTHLY, FORMERLY HEAD OF THE DEPARTMENTS OF PSYCHOLOGY, ANTHROPOLOGY AND PHILOSOPHY, COLUMBIA UNIVERSITY. DR. CATTELL IS CHAIRMAN OF THE EXECUTIVE COMMITTEE OF THE AMERICAN ASSOCIATION AND WAS PRESIDENT IN 1924.



THE NEW YORK ZOOLOGICAL PARK

A HERD OF BISON
IN THE NEW YORK ZOOLOGICAL PARK.

("The Influence of the Glacial Age on the Pre-History of Man"), Reeds ("Weather and Glaciation"), Antevs ("New Maps of Pleistocene Glaciation"), Daly ("Swinging Sea Level of the Ice Age"), Hobbs ("Climatic Zones and Periods of Glaciation") followed by short discussions.

At 4:30 Dr. Frank Leverett will deliver an address on "Glaciations of the Northern Hemisphere."

Evening

Addresses of Welcome at 8 p. m. Mayor James J. Walker and prominent New Yorkers will welcome the association to New York.

At 8:30 Dr. Charles P. Berkey, of Columbia University, will speak on "Recent Discoveries in the Geology of Mongolia," touching on the work done by the Central Asiatic Expeditions of the American Museum.

FRIDAY, DECEMBER 28, 1928

Afternoon

Sixth annual Josiah Willard Gibbs lecture of the American Mathematical Society. Professor G. H. Hardy, of the University of Oxford, will speak on "An Introduction to the Theory of Numbers." 4:30 p. m., at the Casa Italiana.

The Canti film, depicting the behavior of tissue cells *in vitro*, will be shown by Dr. C. A. Kofoid, of the University of California, in the Horace Mann auditorium at 4:30 p. m.

Evening

Seventh annual Sigma Xi lecture will be given under the auspices of the American Association, the American Physical Society and the Society of the Sigma Xi by Dr. Arthur H. Compton, of the University of Chicago, on "What is Light?"

SATURDAY, DECEMBER 29, 1928

Afternoon

General anthropological address by Dr. Franz Boas, of Columbia University, at 4:30, in the Duplex Assembly Room of the American Museum. Subject, "Migrations of Asiatic Races and Cultures to North America."

General showing of American Museum films in the Auditorium at 4:30, including "Simba" and other Martin Johnston films, Dr. Robert Cushman Murphy's "Sea Birds," Dr. Roy Chapman Andrews' "Dinosaurs' Eggs," Dr. Roy Miner's "Under the Sea" and Carl Akeley's "Gorillas."

Symposium on "Salary Adequacy of Academic Families," under the direction of the Committee of One Hundred on Scientific Research, at Columbia University.

Evening

General biologic address by Professor William Morton Wheeler, of Harvard University, "New Tendencies in Biologic Theory."

MONDAY, DECEMBER 31, 1928

Evening

Retiring presidential address of Dr. Arthur A. Noyes, of the California Institute of Technology, on "The Story of the Elements."

TUESDAY, JANUARY 1, 1929

Afternoon

Address in Astronomy by Professor H. H. Turner, F.R.S., of Oxford University, who will represent the British Association at the sessions.

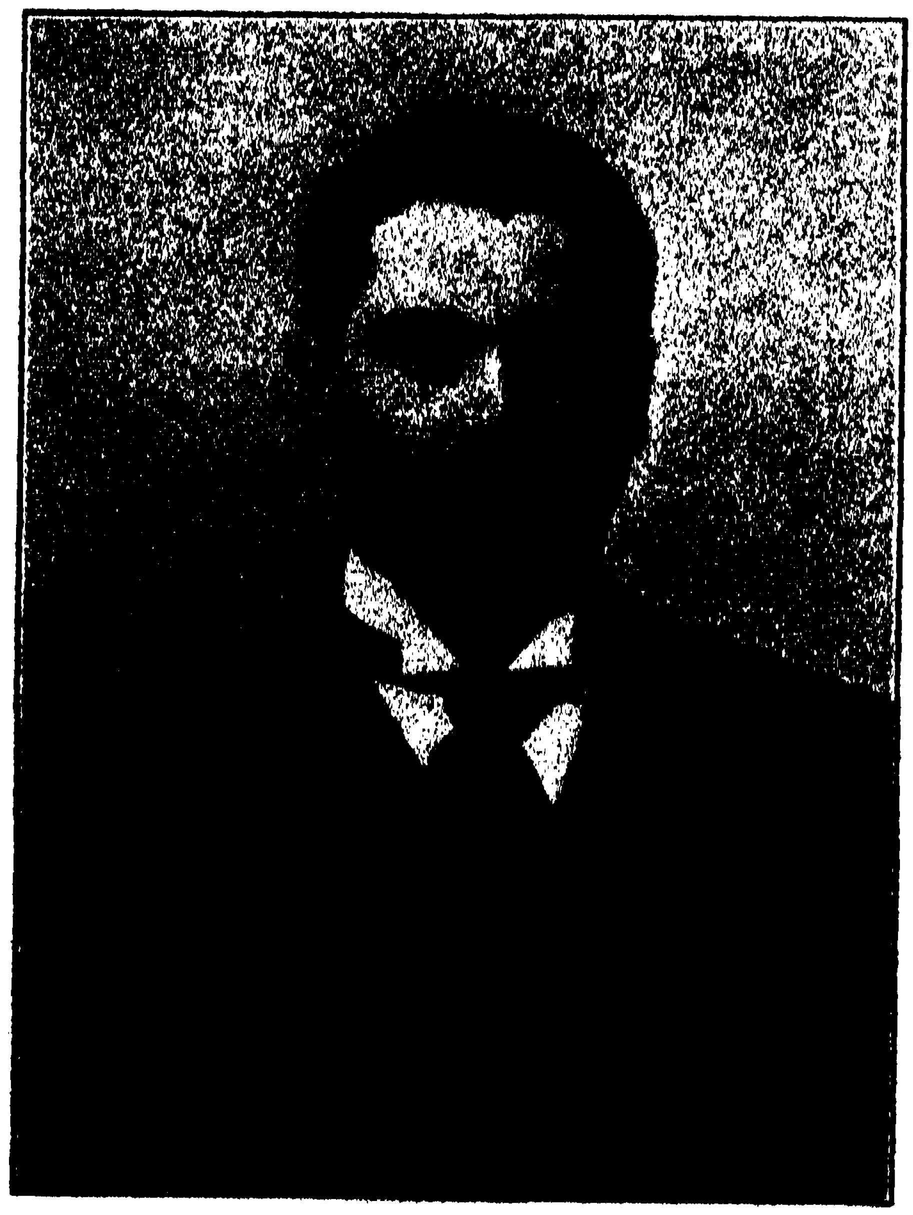
DR. GEORGE B. PEGRAM
PROFESSOR OF PHYSICS, COLUMBIA UNIVERSITY, CHAIRMAN OF THE LOCAL COMMITTEE.

DR. SAM F. TRELEASE
ASSOCIATE PROFESSOR OF BOTANY, COLUMBIA UNIVERSITY, SECRETARY OF THE COUNCIL AND OF THE LOCAL COMMITTEE.

Evening

Dr. Harlow Shapley, of the Harvard Observatory, on "The Galaxies of Galaxies."

Besides these general sessions there will be a number of joint sessions of particular interest to large groups. Among these are the address of Dr. Bailey Willis before the Geological Society on Wednesday evening; the joint meeting of Section G and the Botanical Society of America on Friday afternoon at Teachers College; the joint session of the American Physical, Astronomical



DR. H. H. TURNER
SAVILIAN PROFESSOR OF ASTRONOMY, OXFORD UNIVERSITY, REPRESENTING THE BRITISH ASSOCIATION AT THE NEW YORK MEETING.

and Meteorological Societies with Sections B and D on the same afternoon at the American Museum; the Symposium of the American Society of Naturalists on Saturday afternoon at the American Museum; and the Synthetic Luncheon of Sections C, K and N with the American Institute of the City of New York.

This luncheon will take place at the Hotel Commodore at one o'clock on Saturday afternoon. Colonel Marston T. Bogert, of Columbia University, will

THE NEW YORK BOTANICAL GARDEN
MUSEUM BUILDING.

preside. Dr. Edwin E. Slosson, of Science Service, will discuss "Effects of Synthetic Organic Chemistry on our National Life." Dr. Roger Adams, of the University of Illinois, will discuss "Recent Contributions of Synthetic Organic Chemistry to Medicine." Dr. Charles H. Herty, adviser of the Chemical Foundation and past-president of the Synthetic Organic Chemicals Manufacturers Association, will speak on "Recent Contributions of Synthetic Organic Chemistry to Industry."

The science exhibition, pertinent to all these sessions because of its extensive collection of apparatus and scientific publications, will be as usual under the charge of Major H. S. Kimberly, of the national office. It will be held in the gymnasium of Columbia University and will be well worthy of a visit from workers in any field. Individual societies will in addition have their special exhibits near or in their meeting rooms.

The sixth annual award of the American Association prize of $1,000 will be announced at the close of the meeting. This prize, given by an anonymous donor, is awarded to the author of a noteworthy contribution to science. Any paper presented at the meeting is eligible, whether its author is a member of the association or merely of one of the societies. The announcement of the award committee's selection will be made through the association's news service. Full reports of the daily progress of the sessions will also be supplied to the press of the United States and the world by the news service. The news room will be located in the School of Journalism of Columbia University, where originals and abstracts of papers will be available to the press.

ATTRACTIVE SUNDAY PLANS

Sunday occurs in the middle of the meeting week and will be a time of recreation of a most attractive sort. In the morning excursions to various places of interest will be conducted, as announced by the Entertainment Committee in the program and at the registration offices. The clergy of New York City, whose predecessors formed a substantial percentage of the early membership of the association, have been asked to recognize the present meeting in special sermons. The topic of "Nature and Religion" has been suggested to them by the president of the association as preferable to the more usual and sometimes

THE NEW YORK AQUARIUM

antagonistic "Science and Religion" or "Science and Theology." Every religious denomination was included in this invitation to extend Sunday morning hospitality to the visitors. Many interesting sermons are expected.

On Sunday afternoon the special concert of the Philharmonic-Symphony Society takes place at Carnegie Hall. Every registrant is entitled to a complimentary ticket, which may be obtained at the registration booths. Any seats which are unclaimed by Saturday noon will be available for accompanying members of families, but as the capacity of the hall is limited to 2,700 it was thought wise to allow the first reservations only to members. Out-of-town members are especially urged not to miss this opportunity of hearing one of the finest orchestras of the country in its own hall. The program, with Mengelberg conducting, will be as follows:

Liszt, Prelude.

Tschaikowsky, Adagio, Andante Cantabile.

Wagner, Wotan's Farewell from Die Walkure.

INTERMISSION

Strauss, Ein Heldenleben.

On Sunday evening the trustees of the Metropolitan Museum of Art will set aside long-established precedents and give a reception to the members of the American Association. Guests will enter the building by the park entrance and will proceed through the galleries to the Fifth Avenue gallery, where the reception will take place. There will be music throughout the evening. Every person who registers will receive an invitation to this reception and will thereby acquire a most unusual opportunity of viewing the treasures of the museum.

ENTERTAINMENT PROGRAM

There will be the usual society luncheons and dinners, managed in each case by the society concerned. There will also be a general social program, announced by the entertainment committee as follows:

DAILY EVENTS

Luncheon—In the Flying Bird Hall of the American Museum. 60 cents.

Afternoon Tea—At 4:30 o'clock in the Grace Dodge Rooms of Teachers College, Philosophy Hall of Columbia University, and Education Hall of the American Museum, through the courtesy of the university and museum officers.

Visitors Welcome—Aquarium, Bell Telephone Laboratories, Boyce Thompson Institute, Children's Museum and Brooklyn Botanic Garden, New York Botanical Garden, New York Historical Society, Long Island College Hospital,

College of Physicians and Surgeons, New York Zoological Park, Radio Corporation of America, Russell Sage Foundation. Eugenics Record Office and Station of Experimental Evolution of the Carnegie Institution at Cold Spring Harbor, Rockefeller Institute for Medical Research.

THURSDAY

Reception by the trustees of the American Museum of Natural History, 9:30 p. m., in the Hall of the Age of Man. Invitations will be distributed at registration booths. The entire museum will be open for inspection. There will be music and light refreshments.

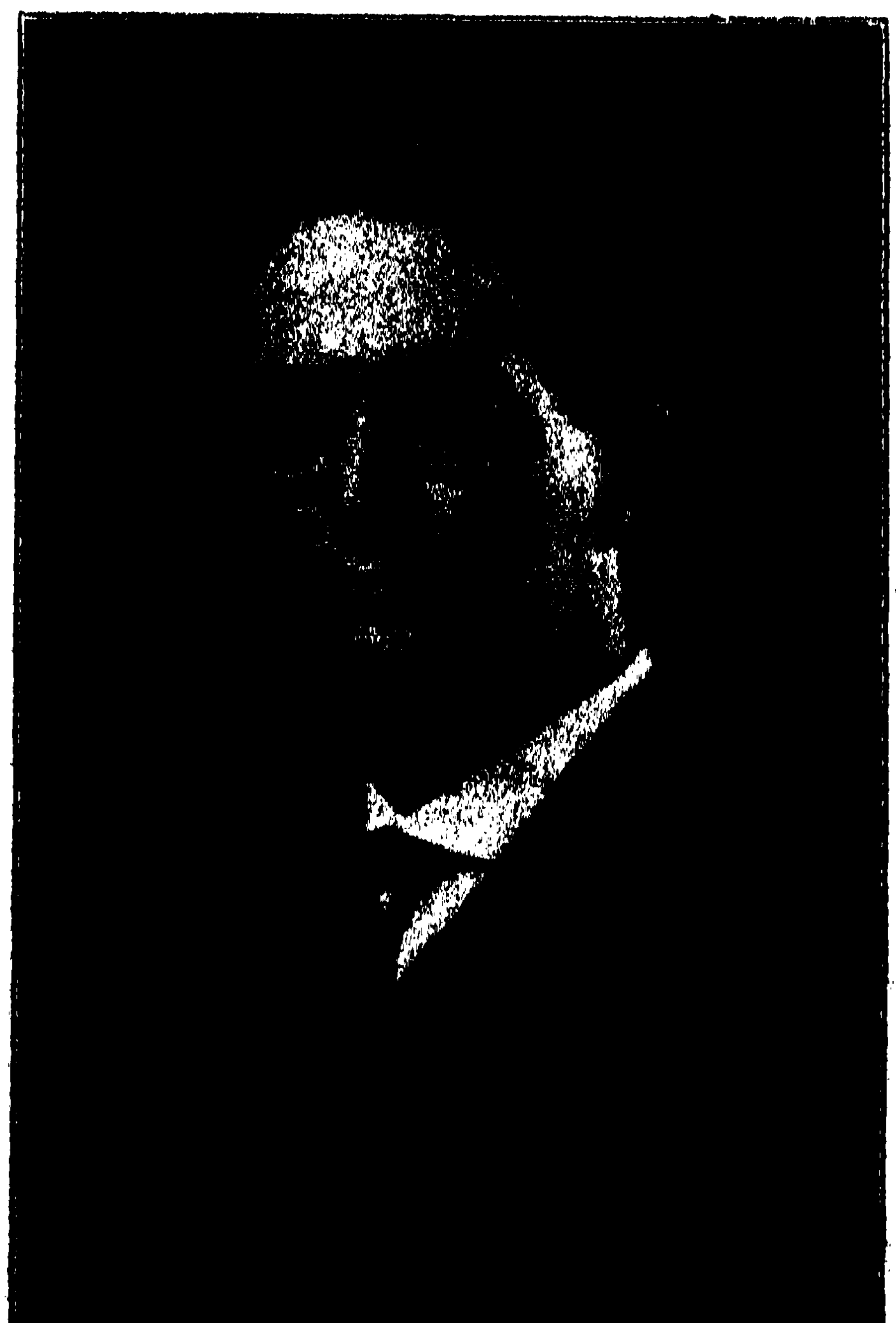
FRIDAY

Informal evening reception at American Museum, following Sigma Xi address.

SATURDAY

Afternoon tea at the Museums of the Peaceful Arts, 24 West 40th Street. Invitations may be obtained at the registration booths.

Informal evening reception at American Museum following general biologic address.



DR. P. W. BRIDGMAN
PROFESSOR OF MATHEMATICS AND NATURAL PHILOSOPHY, HARVARD UNIVERSITY; CHAIRMAN OF THE SECTION OF PHYSICS.

DR. RAY. C. ARCHIBALD
PROFESSOR OF MATHEMATICS, BROWN UNIVERSITY; CHAIRMAN OF THE SECTION OF MATHEMATICS.

SUNDAY

Excursions as announced.

Church services as announced.

Afternoon concert by Philharmonic-Symphony Society at Carnegie Hall. Tickets can be obtained at registration booths.

Evening reception at Metropolitan Museum of Art.

MONDAY

Informal reception following Dr. Arthur A. Noyes' retiring presidential address, Education Hall, American Museum.

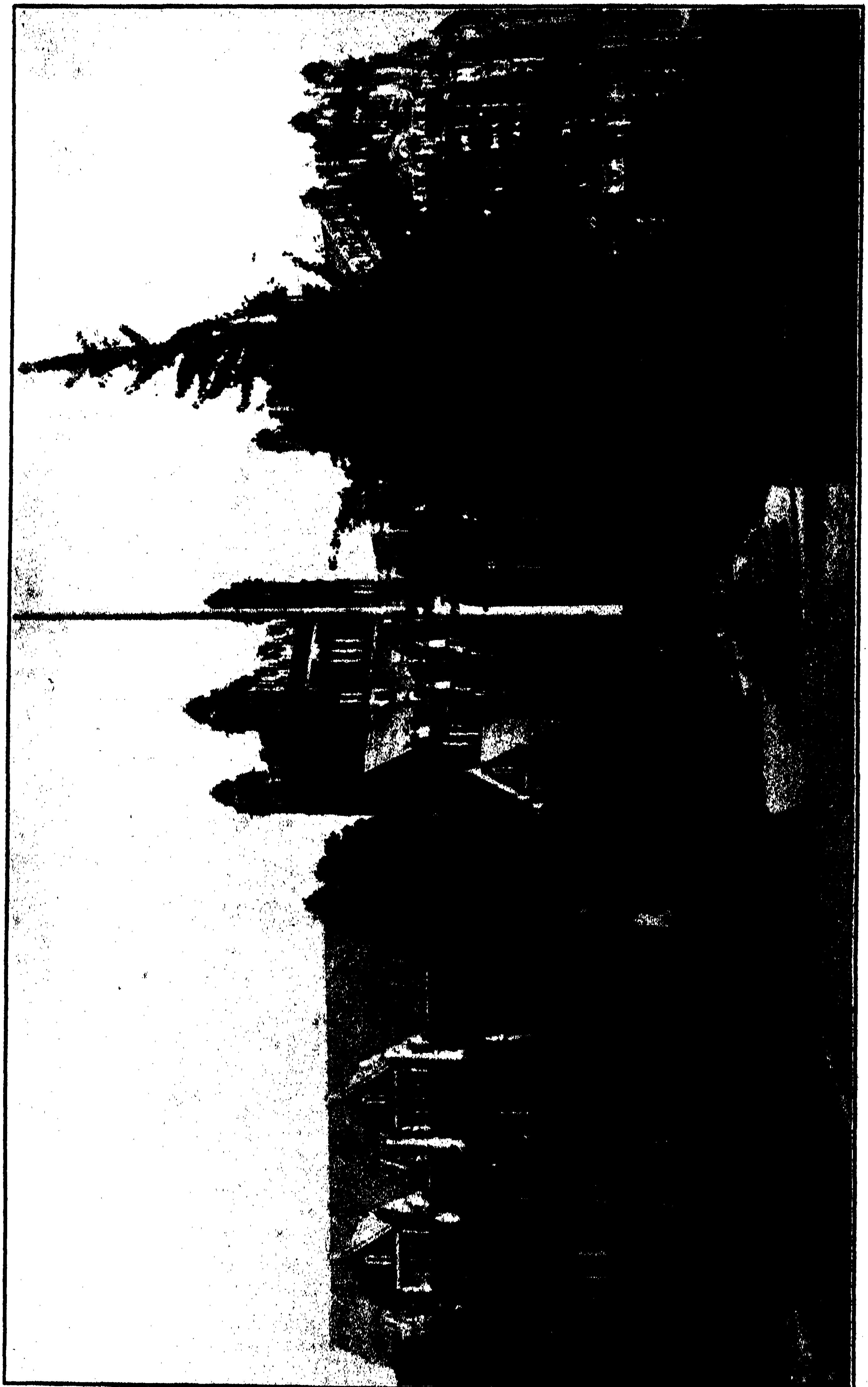
TUESDAY

Informal reception at American Museum, following astronomic address.

MEETING PLACES

Meeting places for the daily sessions of the sections and societies have been announced by Chairman Pegram, as follows:

American Museum: American Anthropological Association, American Folk-Lore Society, American Nature Study Society, American Society of Naturalists, Geological Society of



THE COLLEGE OF THE CITY OF NEW YORK

America, Mineralogical Society of America, Palaeontological Society of America, Sections E and H, Society of Economic Geologists.

Barnard College: American Mathematical Society, Mathematical Association of America, Section A.

Fayerweather Hall, Columbia University: American Psychological Association, Section I.

Metropolitan Museum of Art: American Philological Society, Archaeological Institute of America, College Art Association, Metric Association.

Physics Laboratories, Columbia University: American Astronomical Society, American Meteorological Society, American Physical Society, Sections B and D, Society of the Sigma Xi.

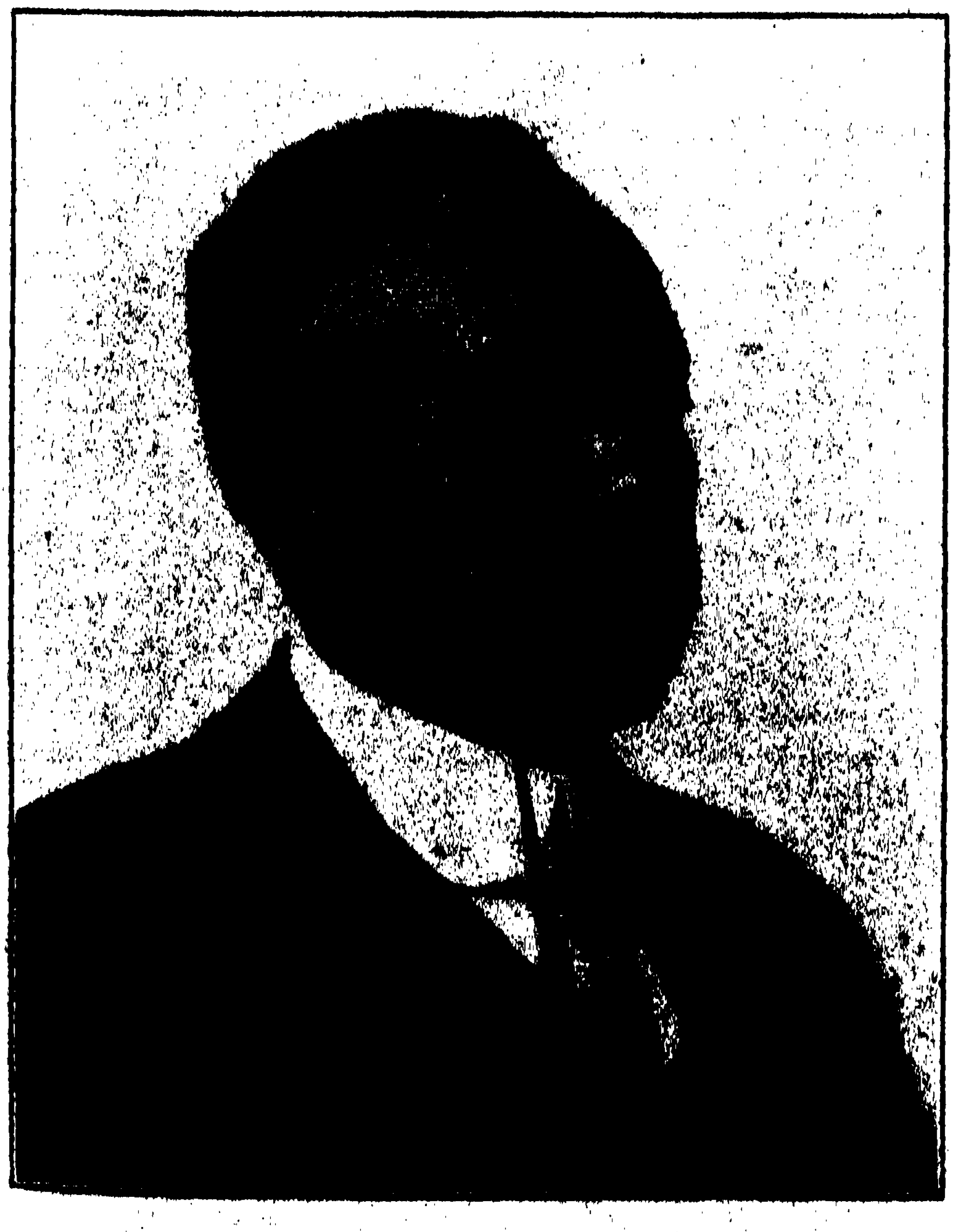
Schermerhorn Hall, Columbia University: American Psychological Association, Section I.

School of Business, Columbia University: Metric Association.

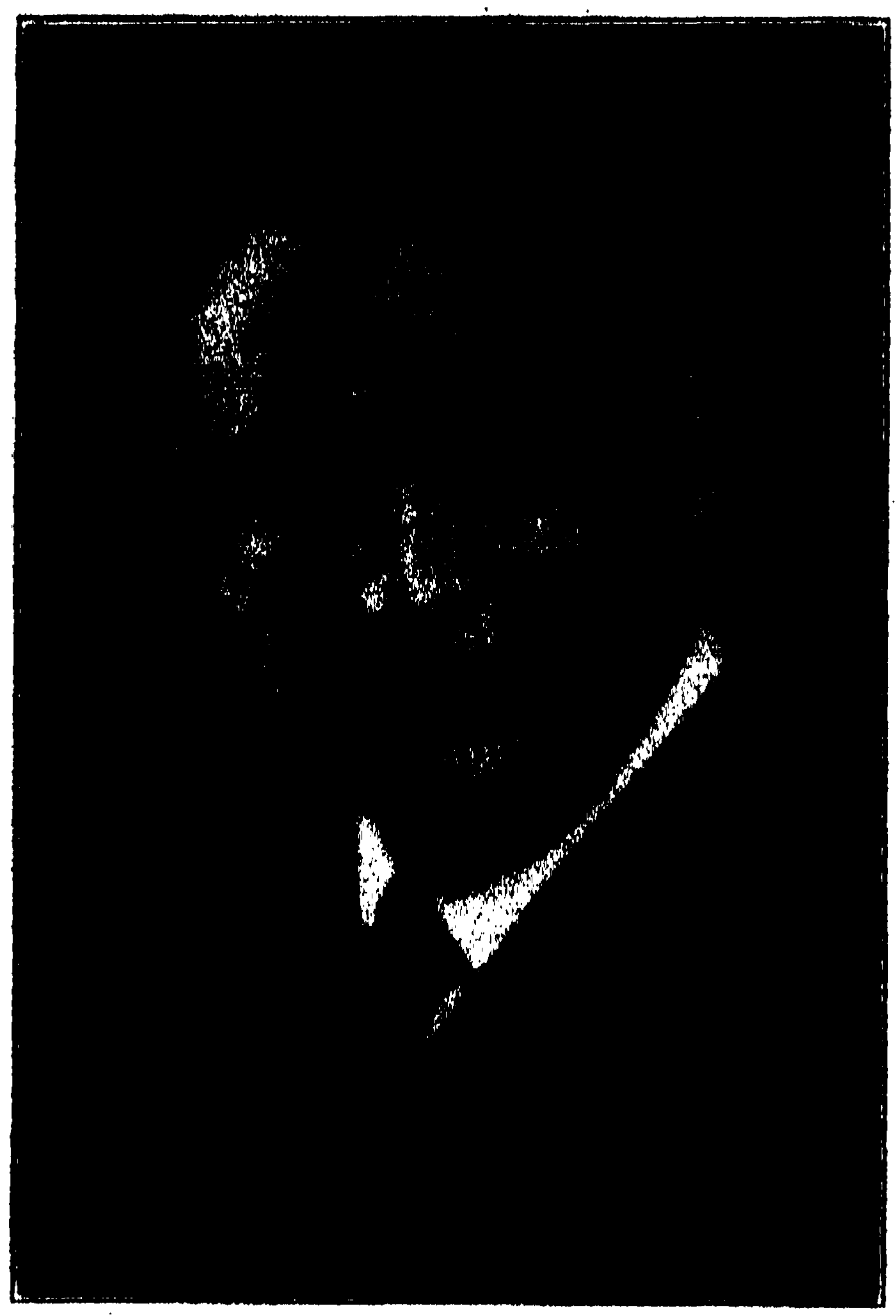
School of Mines, Columbia University: Linguistic Society of America.

American Geographic Society: Association of American Geographers.

Teachers College of Columbia University: American Association of Economic Entomologists, American Fern Society, American Microscopical Society, American Phytopathological Society, American Society of Agronomy,



DR. J. S. PLASKETT
DIRECTOR OF THE DOMINION ASTROPHYSICAL OBSERVATORY, VICTORIA, B. C., CANADA; CHAIRMAN OF THE SECTION OF ASTRONOMY.



DR. C. E. KENNETH MEES
DIRECTOR OF RESEARCH AND DEVELOPMENT, EASTMAN KODAK LABORATORIES; CHAIRMAN OF THE SECTION OF CHEMISTRY.

American Society of Foresters, American Society for Horticultural Science, American Society of Parasitologists, American Society of Plant Physiologists, American Society of Zoologists, Association of Official Seed Analysts, Botanical Society of America, Ecological Society of America, Entomological Society of America, Genetics Sections, Geneticists Interested in Agriculture, Gamma Sigma Delta, Phi Sigma Biological Research Society, Potato Association of America, National Council of Geography Teachers, Sections F, G, O and Q, Sullivant Moss Society.

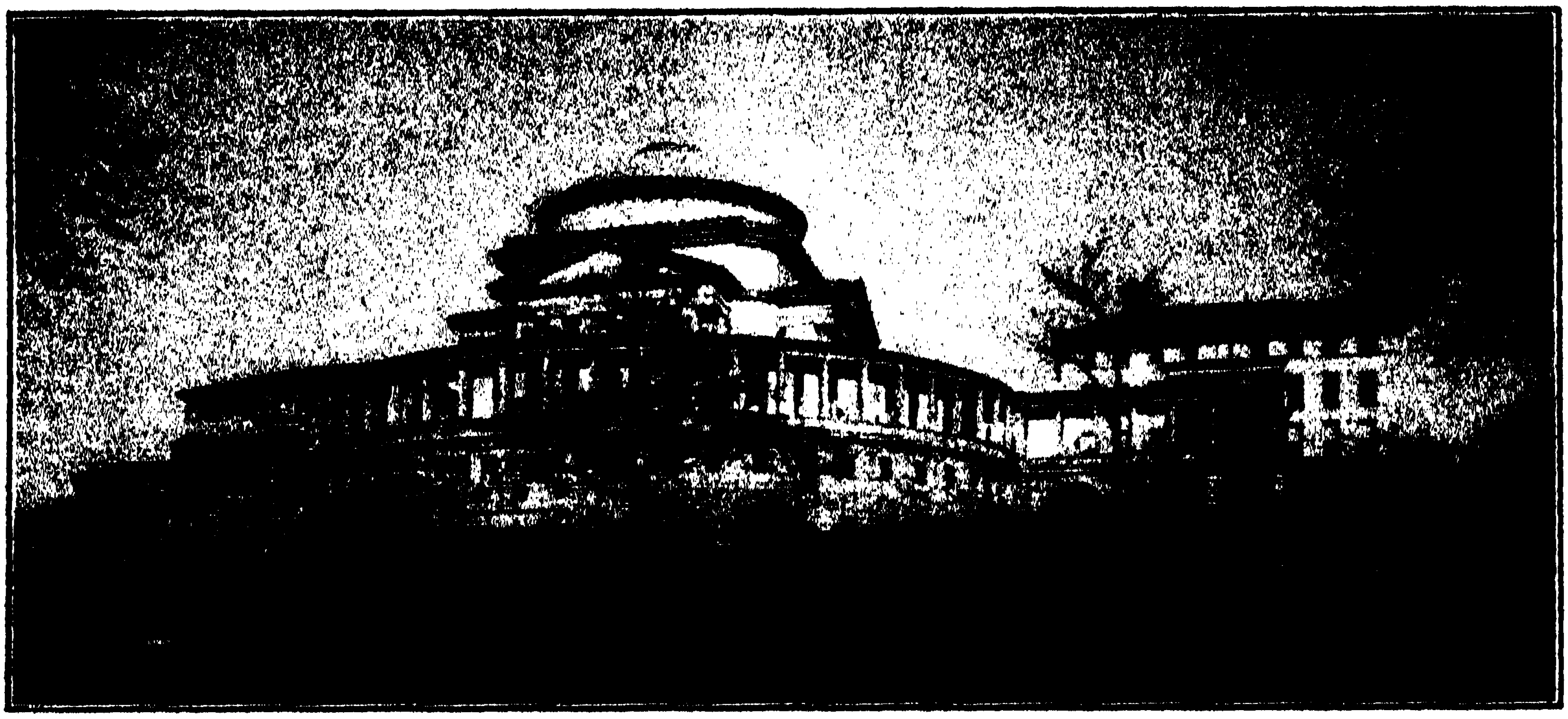
Casa Italiana of Columbia University: American Association of University Professors.

The general local committee, which has worked under President Osborn, Chairman Pegram and Secretary Trelease, consists of:

Henry Fairfield Osborn, *president of the association;* American Museum of Natural History.

Michael I. Pupin, *honorary chairman;* Columbia University.

George B. Pegram, *general chairman and chairman of the special committee on meeting places;* Columbia University.



THE HALL OF FAME
OF NEW YORK UNIVERSITY, LOCATED ON THE CAMPUS AT UNIVERSITY HEIGHTS.

J. McKeen Cattell, *chairman of the association executive committee;* Science Press.

Fred H. Smyth, *local treasurer;* American Museum of Natural History.

Helen Ann Warren, *assistant secretary;* American Museum of Natural History.

Walter H. Eddy, *chairman of the special committee on luncheons.*

Harold A. Fales, *chairman of the special committee on exhibition.*

James T. Grady, *chairman of the special committee on news service.*

Donald E. Lancefield, *chairman of the special committee on local transportation.*

A. Cressy Morrison, *chairman of the special committee on finance.*

Willard L. Severinghaus, *chairman of the special committee on hotels.*

George H. Sherwood, *chairman of the special committee on entertainment.*

The Honorary General Reception Committee consists of:

Henry Fairfield Osborn, *honorary chairman;* American Museum.

Michael I. Pupin, *chairman;* Columbia University.

Hon. James J. Walker, mayor of the City of New York.

Edward Dean Adams.

Chancellor Elmer Ellsworth Brown.

Mrs. Nicholas Murray Butler.

Mrs. Andrew Carnegie.

John J. Carty.

Harvey Nathaniel Davis.

Mrs. Marshall Field.

Mrs. John H. Finley.

Mrs. E. H. Harriman.

Mrs. Frederic S. Lee.

Clarence Mackay.

Frederick B. Robinson.

Owen D. Young.

The Honorary Reception Committee, representing institutions and societies in New York, consists of:

American Chemical Society, New York Section, *Secretary Stephen P. Burke.*

American Geographical Society, *Director Isaiah Bowman.*

Museum of the American Indian, *President George G. Heye.*

American Museum of Natural History, *Director George H. Sherwood.*

American Telephone and Telegraph Co., *Vice President Frank B. Jewett.*

Barnard College, *Dean Virginia C. Gildersleeve.*

Boyce Thompson Institute for Plant Research, *Director William Crocker.*

Brooklyn Botanic Garden, *Director C. Stuart Gager.*

Brooklyn Institute of Arts and Sciences, *President Frank L. Babbott.*

Department of Genetics (Cold Spring Harbor) of the Carnegie Institution of Washington, *Director Charles B. Davenport.*

Casa Italiana, of Columbia University, *Professor John L. Gerig.*

Chamber of Commerce of the State of New York, *Vice President Charles T. Gwynne.*

Chemical Foundation, *Adviser Charles H. Herty.*

American Society of Civil Engineers, *Secretary George T. Seabury.*

Columbia University, *Secretary Frank D. Fackenthal.*

Cooper Union for the Advancement of Arts and Sciences, *Secretary Percy R. Pyne.*

Cornell University Medical College, *Dean Walter L. Niles.*

American Institute of Electrical Engineers, *Secretary F. L. Hutchinson.*

Engineering Foundation, *Director Alfred D. Flinn.*

Fordham University, *Dean Charles J. Deane, S.J.*

General Electric Company, *President Gerard Swope.*

Hispanic Society of America, *President Archer M. Huntingdon.*

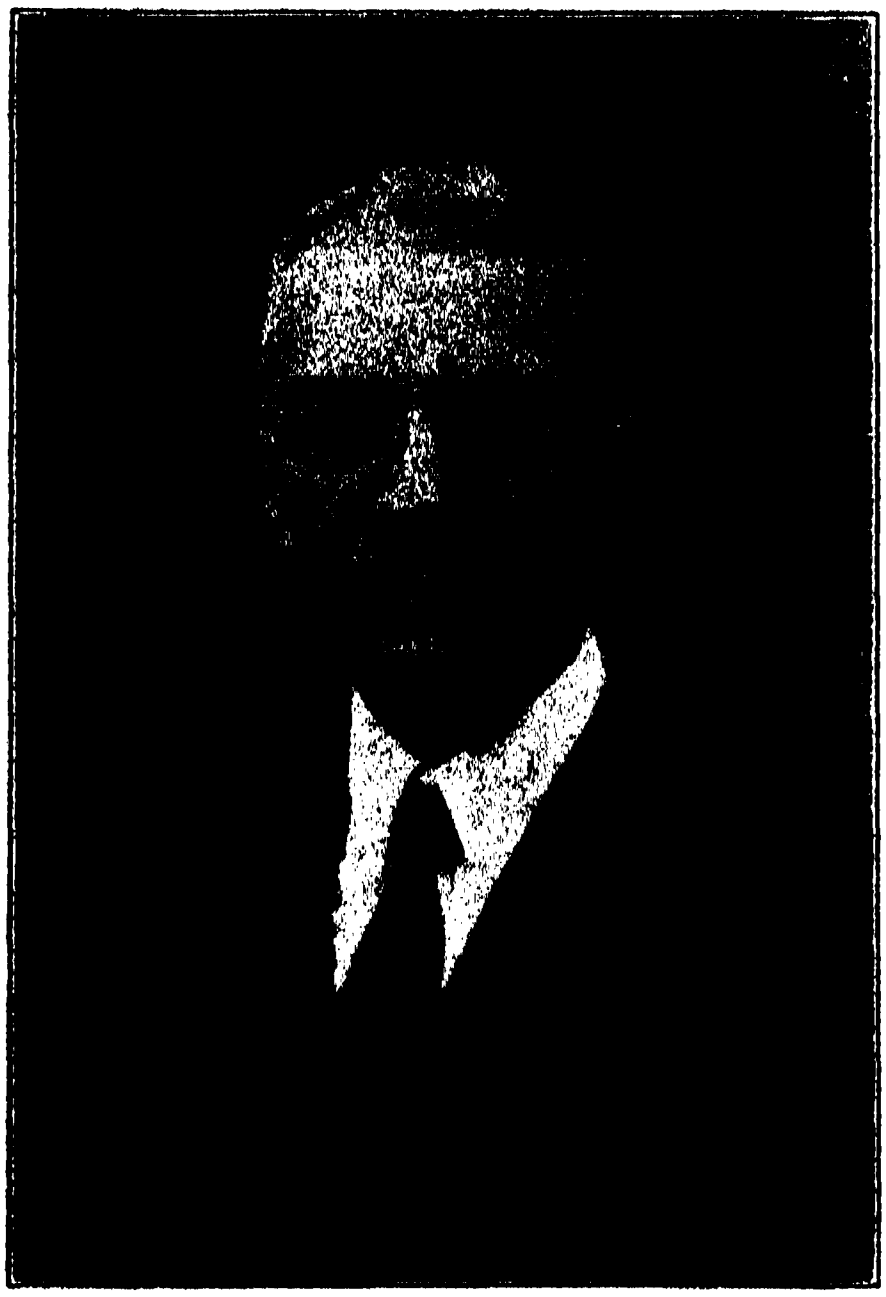
Horace Mann School, *Head Master Rollo G. Reynolds.*

International Education Board, *President Wickliffe Rose.*

International House, *Secretary Harry Edmonds.*

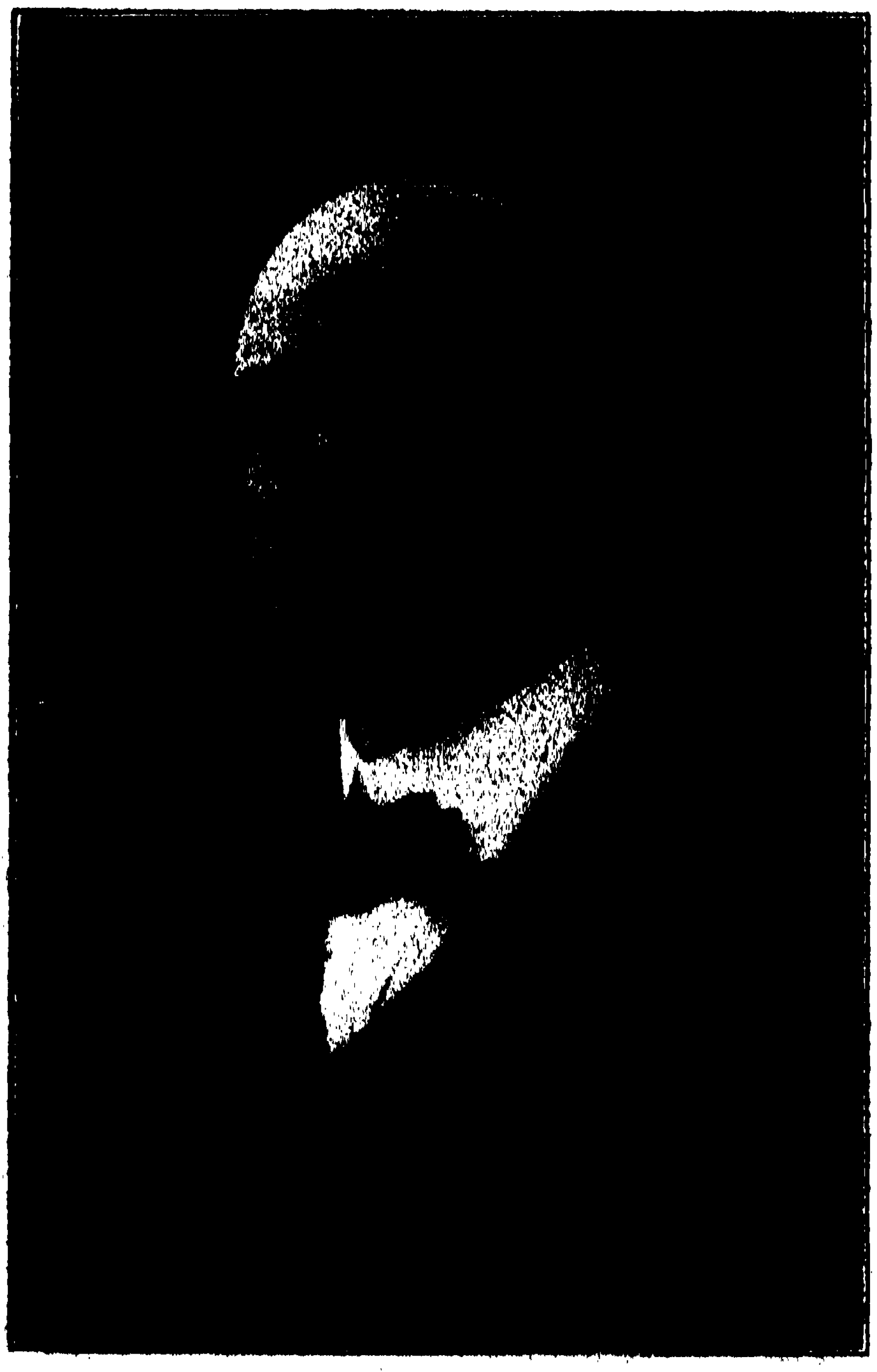
Lincoln School, *Head Master Jesse H. Newlon.*

Biological Laboratory of the Long Island Biological Association, *Director Reginald G. Harris.*



DR. C. A. MOOERS

DIRECTOR OF THE TENNESSEE EXPERIMENT STATION; CHAIRMAN OF THE SECTION OF AGRICULTURE.



DR. R. L. SACKETT

DEAN OF THE SCHOOL OF ENGINEERING AND DIRECTOR OF THE ENGINEERING EXPERIMENT STATION, PENNSYLVANIA STATE COLLEGE; CHAIRMAN OF THE SECTION OF ENGINEERING.

Long Island College Hospital, *Dean Adam M. Miller.*

American Society of Mechanical Engineers, *Secretary Calvin W. Rice.*

New York Academy of Medicine, *Director Linsly R. Williams.*

Merchants Association of New York, *President Lucius R. Eastman.*

Metropolitan Museum of Art, *President Robert W. De Forest, Secretary Henry W. Kent.*

American Institute of Mining and Metallurgical Engineers, *Secretary H. Foster Bain.*

Museums of the Peaceful Arts, *Director Fay Cluff Brown.*

New York Botanical Garden, *Director N. L. Britton.*

College of the City of New York, *President Frederick B. Robinson.*

New York Department of Health, *Commissioner Shirley Wynne.*

New York Historical Society, *President John Abeel Weekes.*

New York Post Graduate Medical School and Hospital, *Dean William D. Cutter.*

New York Telephone Company, *Vice President J. L. Kirkpatrick.*

New York University, *Professor R. R. Renshaw.*

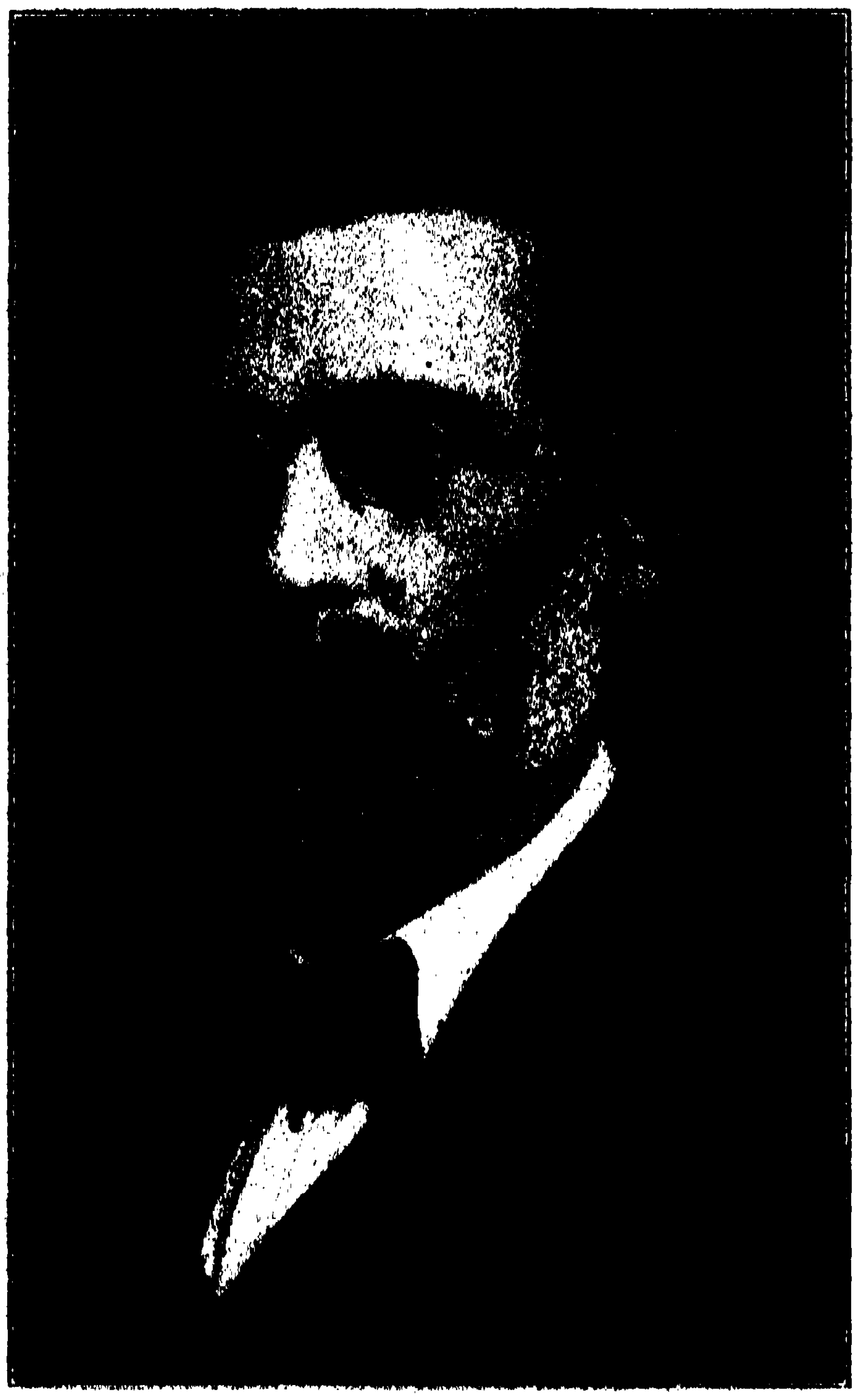
New York Zoological Society, *Director W. Reid Blair.*

THE BROOKLYN BOTANIC GARDEN
LABORATORY BUILDING.

- Hotel Association of New York.
- College of Physicians and Surgeons, *Dean William Darrach.*
- Postal Telegraph-Cable Company, *Secretary Chester G. Burden.*
- Princeton University, *Professor Edwin G. Conklin.*
- Rockefeller Institute for Medical Research, *Manager Edric B. Smith.*
- Radio Corporation of America, *President James G. Harbord.*
- Russell Sage Foundation, *General Director F. M. Glenn.*
- New York Academy of Sciences, *Secretary Roy Waldo Miner.*
- Stevens Institute of Technology, *President Harvey N. Davis.*
- Teachers College, *Dr. Goodwin B. Watson.*
- University of the State of New York, *Commissioner Frank Pierrepont Graves.*
- Museum of the State of New York, *Dr. Charles C. Adams.*
- Western Union Telegraph Company, *Vice President G. M. Yorke.*
- Yale University and the Peabody Museum, *Professor Richard S. Lull.*

In placing this program and these meeting arrangements at the disposal of the members, the officers of the association have worked in the hope that every member registering for the sessions will make full use of this opportunity of realizing the fourfold objects of the association. When applied to the individual member these are briefly: (1) to promote intercourse among scientific workers in different parts of America, and thereby to aid knowledge of each other's methods, ideas, problems and personality; (2) to provide familiarity with other scientific societies and institutions, through cooperation and personal inspection; (3) to give a stronger, more general impulse and more systematic direction to scientific research, through the exchange of ideas and the establishment of a definite time and place of publication; (4) to procure for the labors of scientific men increased facilities and a wider usefulness. This last object is particularly well accomplished in a city

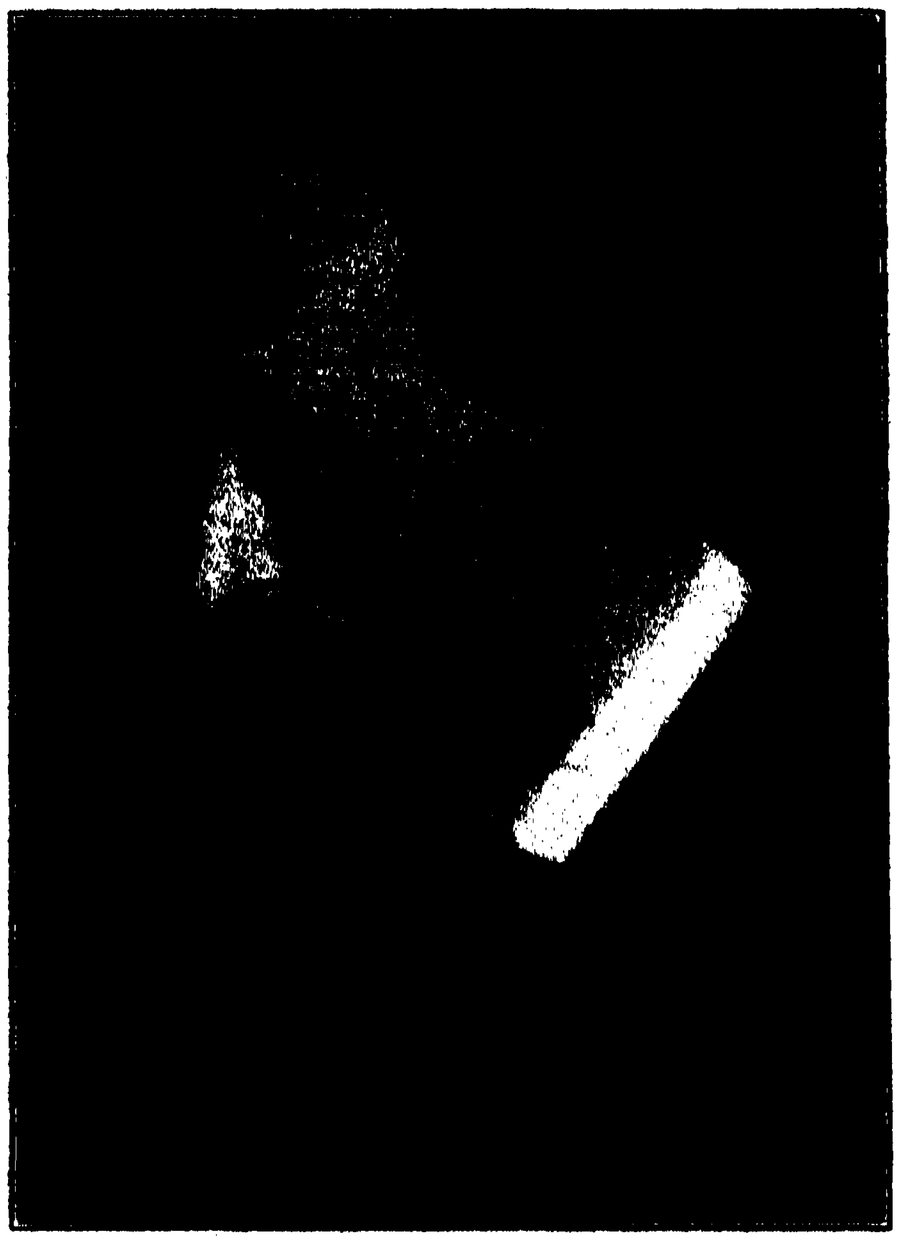
like New York, where public interest is widely aroused and where the leaders of commerce and industry can be brought face to face with the men whose inventions and painstaking investigations make possible a large measure of the material as well as intellectual prosperity of the country.



DR. FRANK LEVERETT
LECTURER IN GLACIAL GEOLOGY, UNIVERSITY OF MICHIGAN; CHAIRMAN OF THE SECTION OF GEOLOGY AND GEOGRAPHY.

HISTORY OF THE AMERICAN ASSOCIATION

The American Association for the Advancement of Science is a national organization of scientific workers with permanent headquarters in the Smithsonian Institution Building at Washington, D. C. Professor Burton E. Livingston, of the Laboratory of Plant Physiology of the Johns Hopkins University, is permanent secretary of the association, and is assisted by Mr. Sam Woodley, mana-

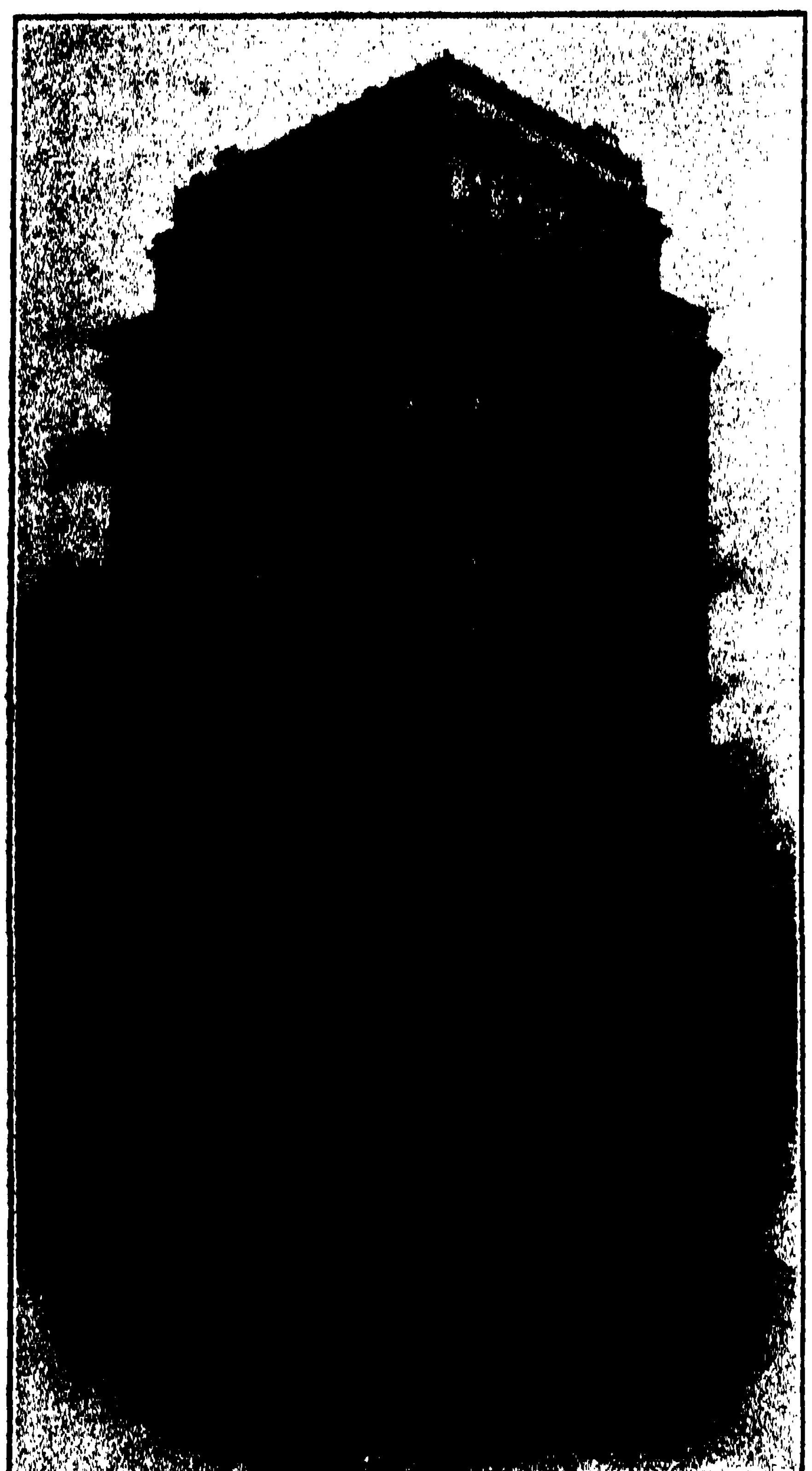


DR. A. J. GOLDFORB
PROFESSOR OF BIOLOGY, COLLEGE OF THE CITY OF NEW YORK; CHAIRMAN OF THE SECTION OF MEDICAL SCIENCES.

DR. FAY-COOPER COLE
PROFESSOR OF ANTHROPOLOGY, UNIVERSITY OF CHICAGO; CHAIRMAN OF THE SECTION OF ANTHROPOLOGY.

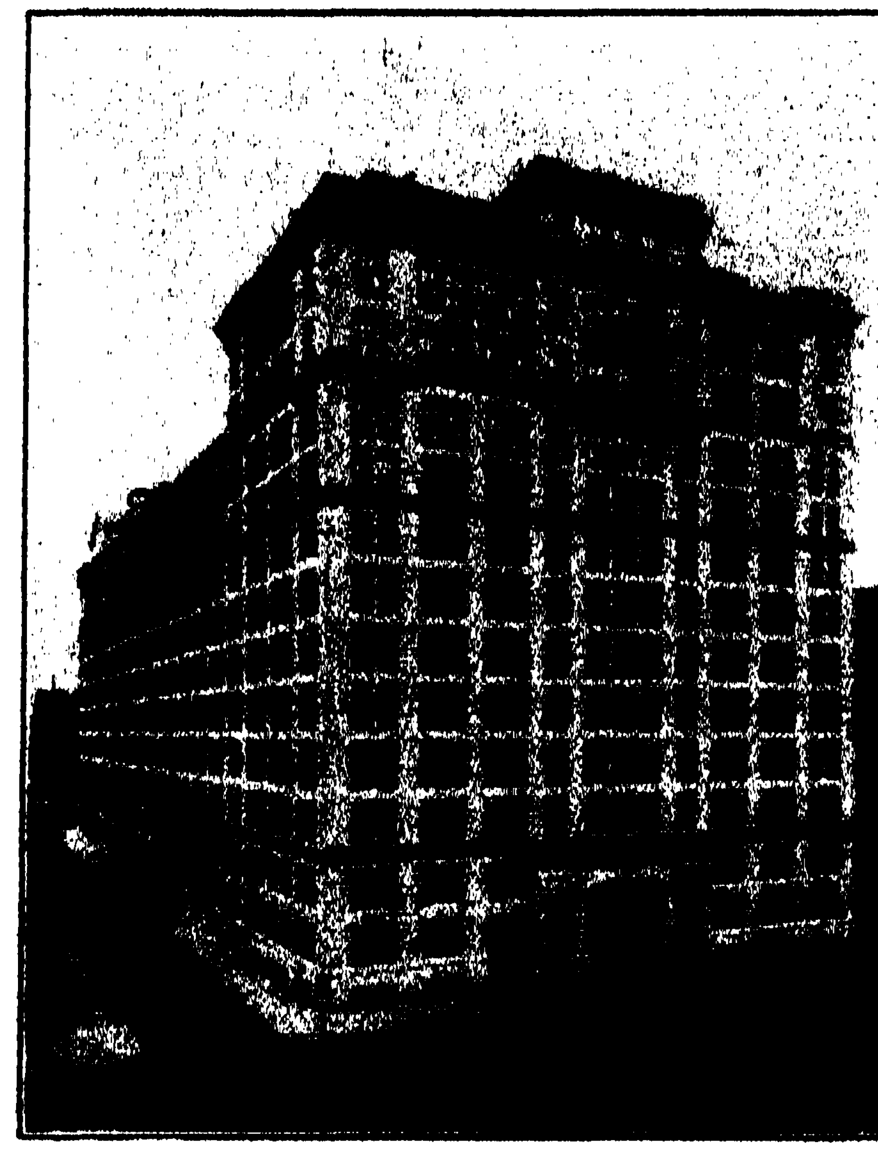
ger of the Washington office. Other officers are:

President, Henry Fairfield Osborn; American Museum of Natural History, New York; *retiring president,* Arthur A. Noyes; California Institute of Technology, Pasadena, Calif.; *general secretary,* W. J. Humphreys; Weather Bureau, Washington, D. C.; *treasurer,* John L. Wirt; Carnegie Institution of Washington, Washington, D. C.; *the vice presidents,* the chairmen of the sections.



UNITED ENGINEERING SOCIETIES BUILDING

The association is composed of sections in mathematics, physics, chemistry, astronomy, geology and geography, zoological sciences, biological sciences, anthropology, psychology, social and economic sciences, historical and philological sciences, engineering, medical sciences, agriculture and education. A number of national scientific societies are associated with each section and usually meet at the same time, although their programs are sometimes separate. Each



THE BELL TELEPHONE LABORATORIES

MUSEUMS OF THE PEACEFUL ARTS

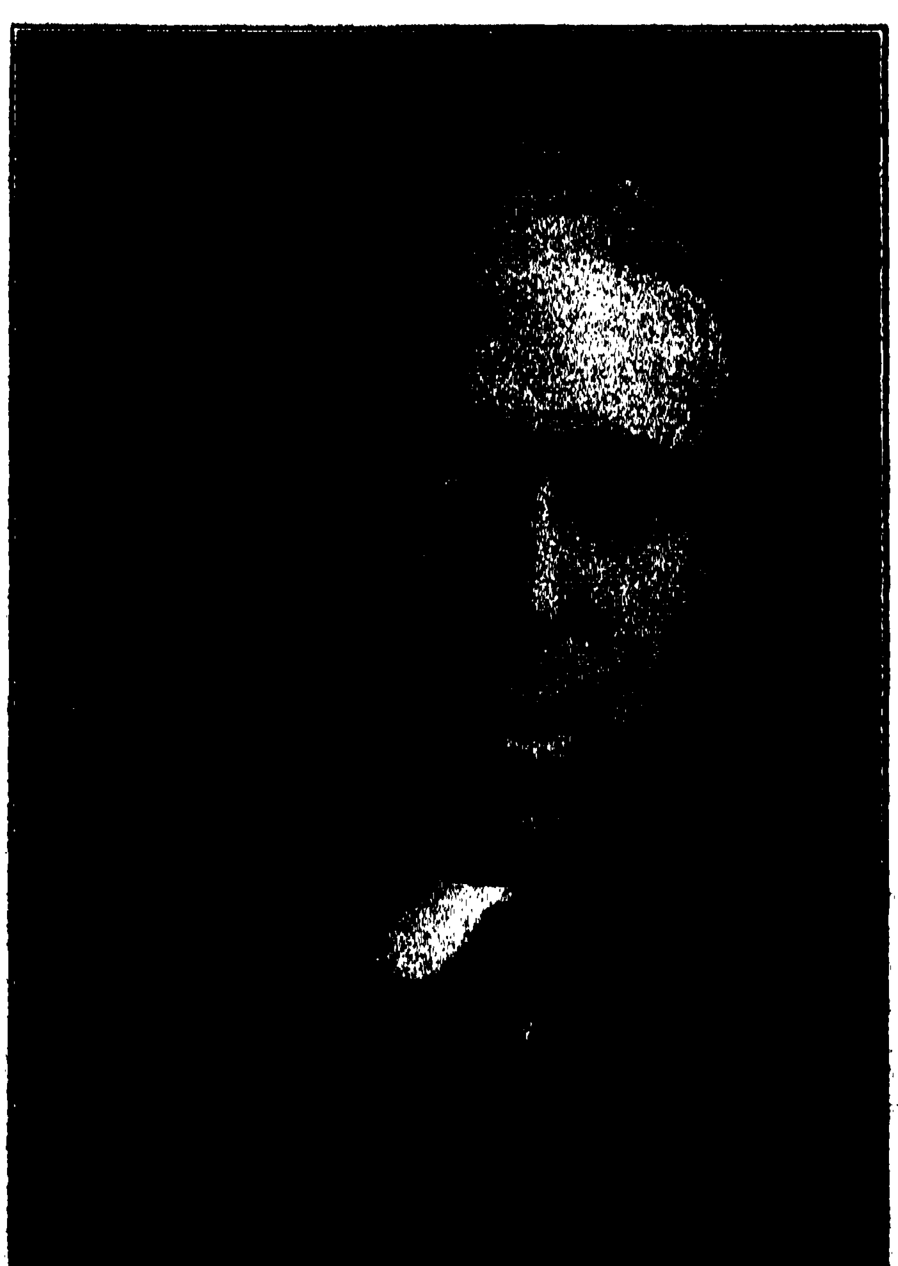
ONE OF THE HUNDRED OR MORE VISITOR-OPERATED EXHIBITS AT THE MUSEUM AT 24 WEST 40TH STREET. THE PHOTOGRAPH ABOVE SHOWS A VISITOR MEASURING IN 1/100,000THS OF AN INCH, BY MEANS OF LIGHT WAVES, THE DEFLECTION OF A STEEL RAIL CAUSED BY THE SLIGHT PRESSURE OF A FINGER ON THE TOP OF THE RAIL.

section has its own officers, the chairman being a member of the association council. These officers arrange the section programs for the annual meetings of the association.

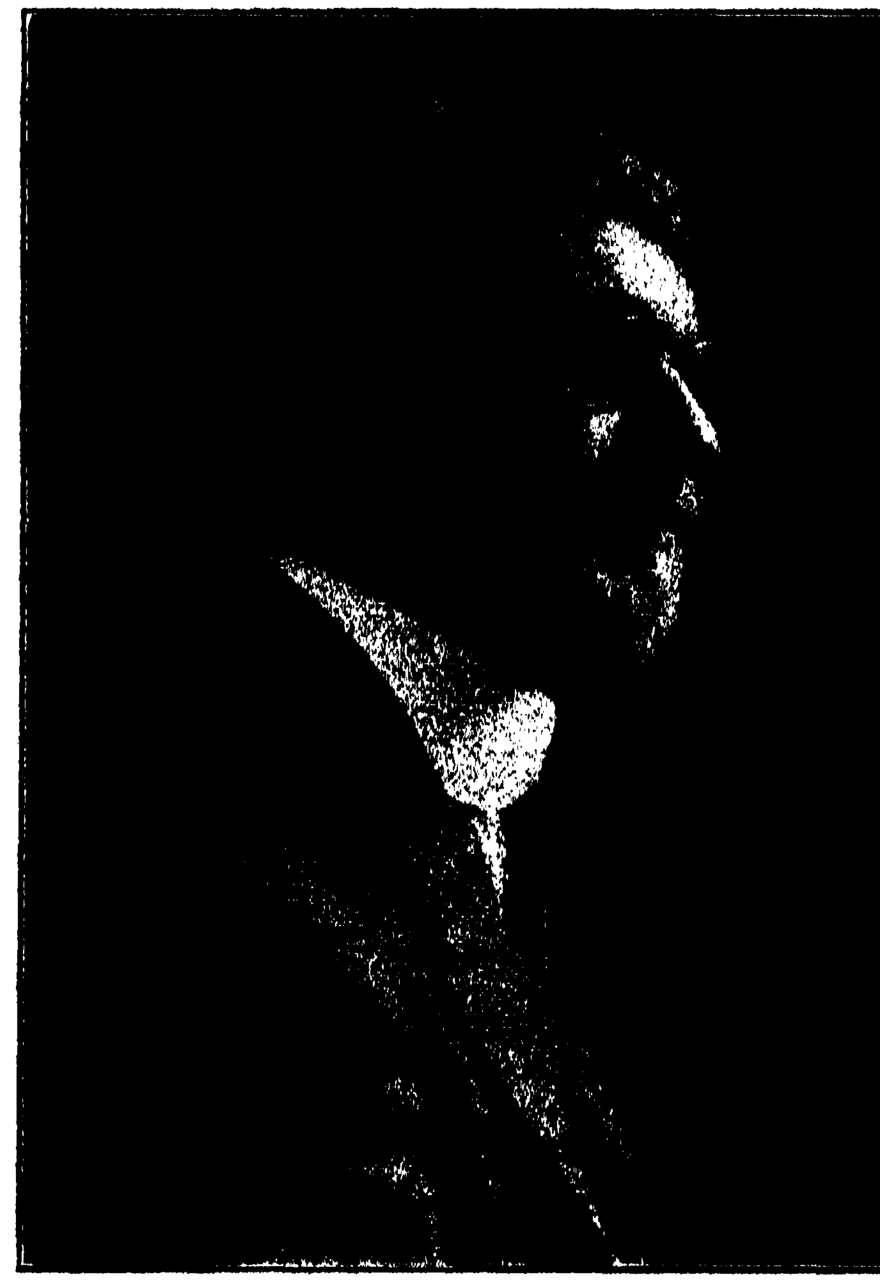
The annual meetings take place during Christmas week. Once in four years they are held in Washington, Chicago or New York. Other cities are visited in intervening years. In addition to the Christmas meetings and occasional other meetings the association actively supports research workers, endeavors to encourage friendly cooperation among scientific institutions and individuals and to aid scientific publications.

Membership in the association carries with it annual subscription to either *Science* or THE SCIENTIFIC MONTHLY, in both of which accounts of association activities appear.

This great association of the English-speaking scientists of North America



DR. TRUMAN L. KELLEY
PROFESSOR OF EDUCATION AND PSYCHOLOGY, STANFORD UNIVERSITY; CHAIRMAN OF THE SECTION OF EDUCATION.



DR. HOWARD C. WARREN
PROFESSOR OF PSYCHOLOGY, PRINCETON UNIVERSITY; CHAIRMAN OF THE SECTION OF PSYCHOLOGY.

meets in New York City for the eighty-fifth conference of its history. Five of its past presidents are residents of New York and will attend the sessions. Their photographs accompany this article. They are Edmund B. Wilson, J. McKeen Cattell, Simon Flexner, Michael I. Pupin, John Merle Coulter and Henry Fairfield Osborn.

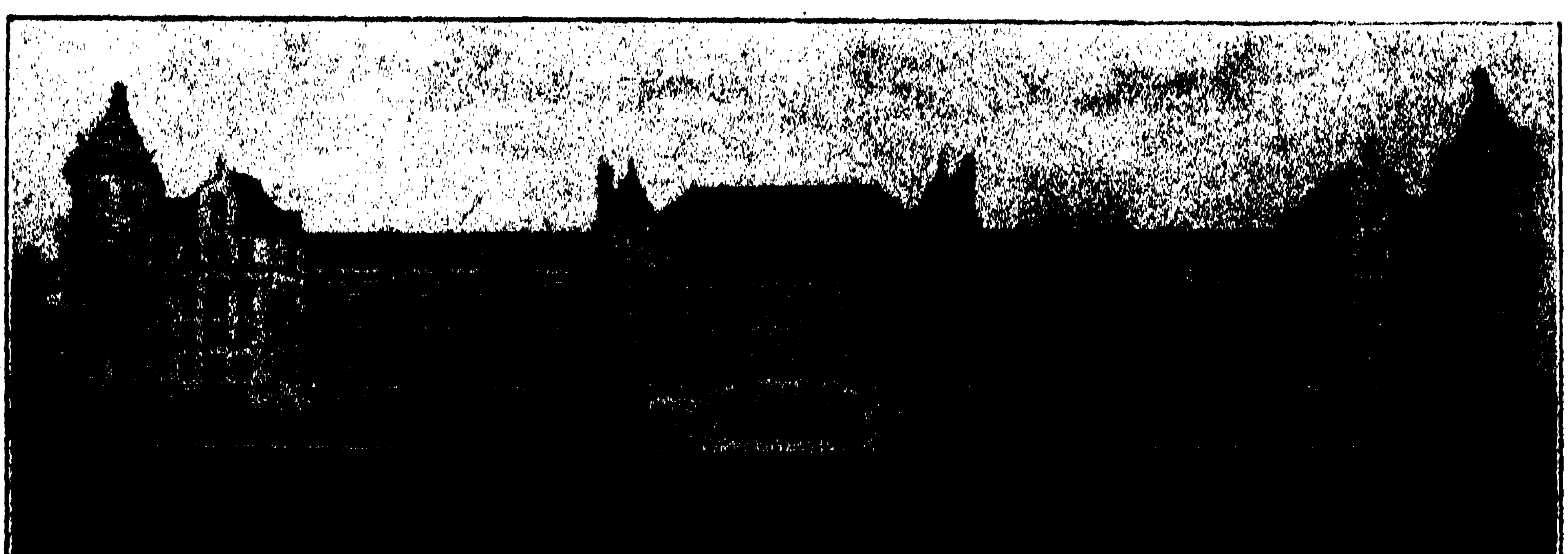
Although this is the eighty-fifth meeting of its corporate career the American Association really dates back to 1839 and the formation of the Association of American Geologists by members of the New York Board of Geologists. Dr. Ebenezer Emmons, W. W. Mather, Edward Hitchcock and Lardner Vanuxem were moving spirits in this organization, which took formal being at a meeting in the Hall of the Franklin Institute of Philadelphia on April 2, 1840. There were eighteen members of the association, five of them from the New York

Survey. The Rev. Edward Hitchcock was chairman.

Three years later the geologists' association widened its scope and became the Association of American Geologists and Naturalists. Accounts of the meetings of this body were published in the *American Journal of Science*. There were seventy-seven members who attended the meetings or presented communications. Sixteen of these men were professors and four clergymen. This was 6 per cent. less theology than in the British Association, which had been organized in 1831 with 25 per cent. of its members clerics, including the eminent geologists Buckland and Sedgwick.

In 1847 it was decided to further extend the scope of the association and on September 20, 1848, again at Philadelphia, the American Association for the Advancement of Science was established. William C. Redfield, the first president, was a meteorologist and physicist. He was a prime mover in the formation of the larger association, although the actual business of formulating rules was done by H. D. Rogers, Benjamin Peirce and Louis Agassiz. Largely through Agassiz's influence the association was modeled after the British Association for the Advancement of Science, under which he had worked. Agassiz was also responsible for the object of interesting the general public in scientific accomplishment, an aim of his life which was realized by the establishment of many of our national museums, notably the Cambridge Museum of Comparative Anatomy and the American Museum of Natural History and in the science departments of numerous American universities.

The year 1848 knew political unrest and the opening up of a new era in the history of the United States. Revolutionary struggles racked Europe, but in America the Mexican War closed and the treaty signed in February brought a vast new territory under our flag. Covered wagons started westward. Gold was discovered in California. Exploring expeditions added zest to the geological study of the day. The postal connection between the United States and Great Britain stimulated international contacts, while the completion of the High Bridge Aqueduct in New York City was an engineering event. Spiritualism was given its first public demonstration and Mormons were persecuted at Nauvoo, Illinois. Also, in July, the great woman's suffrage movement held its first woman's rights convention. It was a year of beginnings and among them the American Association, whose eighty-five years of life have brought a growth hardly dreamed of in 1848.



—From the American Museum of Natural History

THE AMERICAN MUSEUM OF NATURAL HISTORY

THE SCATTERING OF ELECTRONS BY CRYSTALS[1]

By Dr. C. J. DAVISSON

BELL TELEPHONE LABORATORIES, NEW YORK

THE special interest which attaches to the experiments with electrons made by Dr. Germer and me is due to their lending a certain quite definite support to the hypothesis from which has sprung the wave theory of mechanics—the hypothesis put forward by de Broglie in 1924 that just as it is convenient in certain circumstances to regard X-rays as particles rather than as waves, so it will be found convenient in certain circumstances to regard electrons as waves rather than as particles.

I should like to be able to state that Dr. Germer and I were greatly impressed by the reasonableness of this hypothesis, and that we set about at once to devise an experiment in which the wave nature of electrons would be revealed by the phenomenon of interference. The fact is, however, that the considerations which led us to investigate the scattering of electrons by a crystal of nickel were of quite a different sort. And it may be of some interest if, in describing the experiments, I tell what these considerations were.

Our interest in the general subject of electron scattering dates from a simple but significant observation which we chanced to make in the Bell Telephone Laboratories in the year 1919. What we observed was that when a beam of electrons is directed against a metal target some of the incident particles are scattered without appreciable loss of energy. Electrons having the same speed as those in the incident beam stream out in all directions.

This was in 1919, and at that time one was restricted in the views one might hold in regard to a phenomenon of this kind. Scattering without loss of energy might result from a collision of the electron with a single atom, or from collisions with two or more atoms—and these exhausted the possible explanations. We convinced ourselves that single collisions were much the more likely, and set about investigating the way in which these full-speed electrons are distributed in direction. We pictured the electrons being swung around in the strong field within the atom, and hoped to find out from their distribution-in-direction something about this atomic field. What we were attempting, in short, were atomic explorations similar to those of Sir Ernest Rutherford and his collaborators, but explorations in which the probe should be an electron rather than an alpha particle.

Our earliest observations were made upon electrons scattered by targets of polycrystalline nickel. In 1925 Dr. Germer and I were continuing these observations when we discovered, much to our surprise, that the way in which the full-speed scattered electrons are distributed in direction depends upon the size of the crystals in the target. If the crystals are small so that the number under bombardment is great the distribution is simple and the same for different targets—but if the crystals are large so that scattering occurs from a few only, the distribution is irregular; there are great concentrations of scattering in some

[1] Based on an address given by invitation before Section A, British Association for the Advancement of Science, Glasgow, September, 1928.

directions, and only comparatively weak scattering in others.

Curves illustrating this difference between the scattering by small and large crystals—or rather, by many and few crystals—are shown in Fig. 1. But first I must explain how these curves were obtained. The method of observation will be made clear by the diagram on the left. Electrons emitted by a tungsten filament are accelerated and some of these, after passing through a series of apertures, emerge in a narrow beam or pencil from the "electron gun." This beam is directed against the target, from which electrons of various speeds stream out in all directions. The intensity of scattering in different directions is then determined by measuring the current received by the inner box of the collector as it is moved from one position to another. We are interested primarily in only those electrons which leave the target with the same speed, or nearly the same, as those in the incident beam. Our observations are restricted to this class by maintaining a retarding potential of appropriate magnitude between the parts of the collector. The distribution curves shown in Fig. 1 are both for nickel, and are both for bombarding potential 75 volts. The one on the left is typical of the scattering by a target comprising many small crystals, while that on the right was obtained when the number of crystals under bombardment was only ten or a dozen.

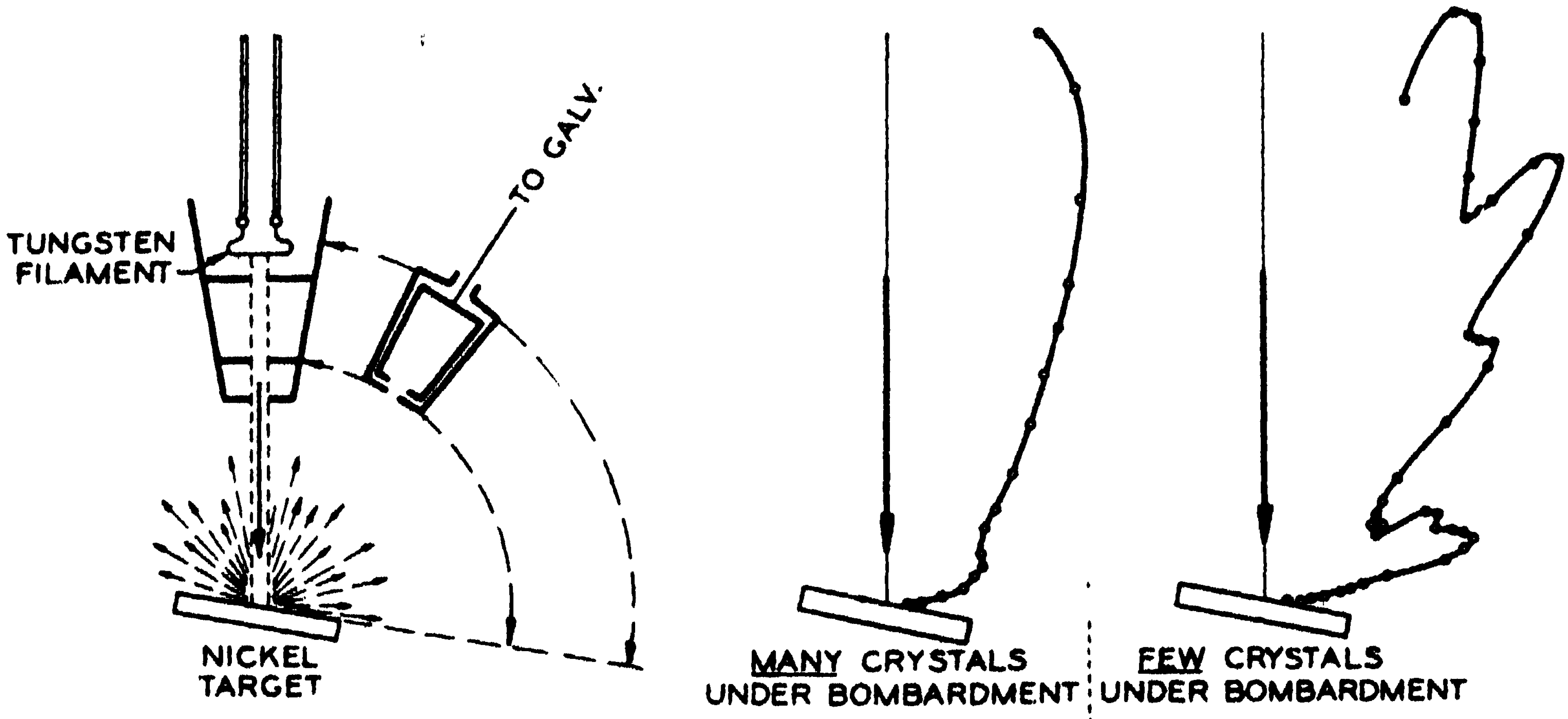


FIG. 1. ELECTRON SCATTERING CURVES OBTAINED FROM BLOCKS OF NICKEL CONTAINING RESPECTIVELY MANY CRYSTALS AND FEW CRYSTALS.

It was this result rather than de Broglie's hypothesis which led us to investigate the scattering by a single crystal. We were convinced that this irregular pattern could result only from a marked dependence of the intensity of scattering upon crystal direction, and we set about to find what this dependence might be. And now I must go somewhat into detail in describing the experimental conditions which we tried to realize in these new experiments, and to do this I shall make use of two diagrams.

Nickel forms crystals of the face-centered cubic type, the edge of the unit cube being 3.51 A in length. The block of 27 unit cubes shown on the left in Fig. 2 will serve as a symbol to represent the crystal which we eventually produced and with which we began our investigation. First we cut through this structure at right angles to one of the cube diagonals, exposing the triangular face shown in the central figure. We

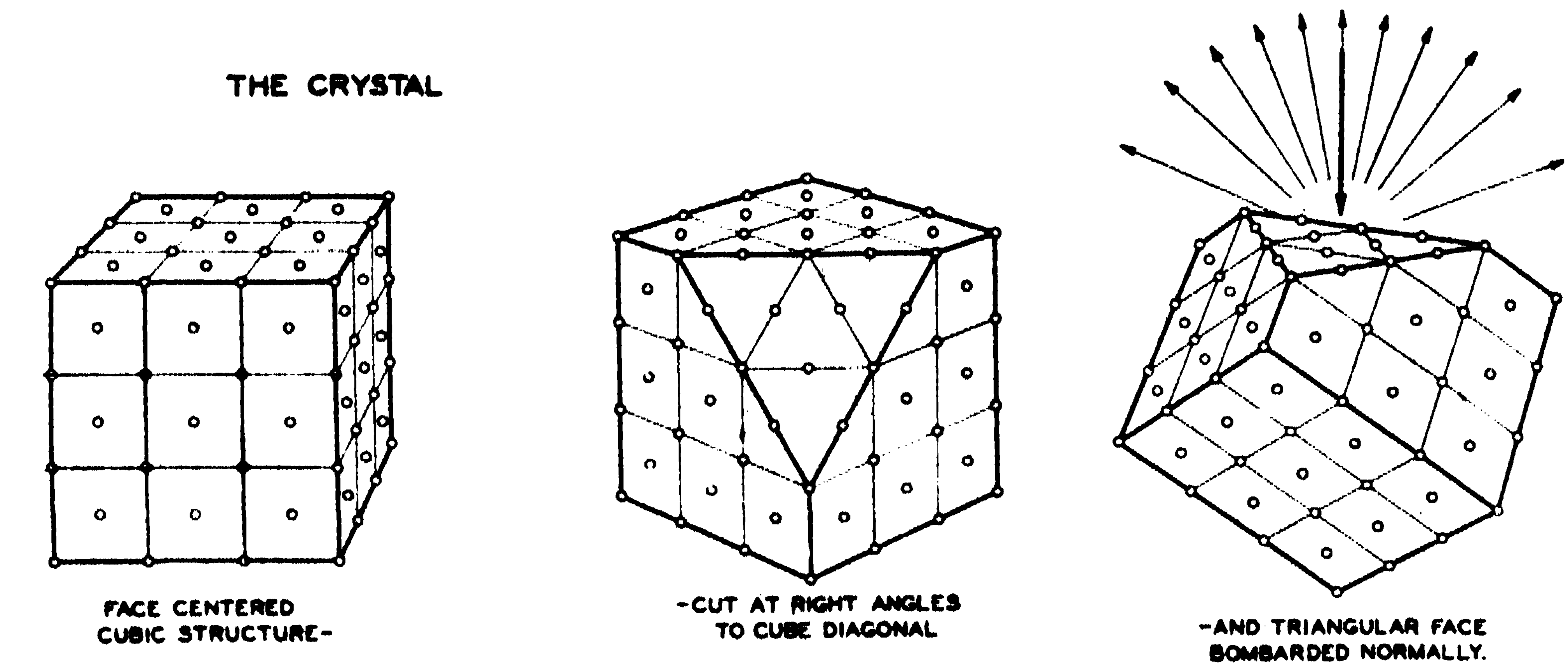


FIG. 2. SCHEMATIC REPRESENTATIONS OF THE FACE-CENTERED CUBIC CRYSTAL OF NICKEL.

then arranged to bombard this newly formed surface at normal incidence as illustrated on the right.

We wished, of course, to measure the intensity of scattering not only in a single plane as in our previous experiments, but in various planes or azimuths about the incident beam. To accomplish this we adopted the arrangement shown in Fig. 3. The collector could be rotated about the bombarded area in a single plane as before, but in addition the crystal itself could be rotated about the axis of the incident beam, so that any azimuth of the crystal could be brought into the plane of the collector. It is clear, of course, that a certain restriction is imposed by the symmetry of the crystal upon the type of scattering pattern that can be observed with this arrangement; the threefold symmetry of the crystal is necessarily reflected in a threefold symmetry of the pattern. The principal azimuths of the crystal are the set of three which include the apexes of the triangle, the set of three which include the mid-points of the sides of the triangle, and the set of six lying parallel to these sides. These we designate the A-, B- and C-azimuths respectively.

It was in April, 1925, that we set out to produce a nickel crystal of appropriate size for this experiment, and it was May, 1926, before the arrangement illustrated here was completed and we were ready to make observations. In the meantime the suggestion had been made by Elsasser in Germany that evidence of the interference of de Broglie waves would be found in the scattering of electrons by a single crystal. We knew of this suggestion, but did not think highly of it. We could see no evidence of a wave phenomenon in any of our previous results, and we did not expect to find any in these new experiments. Our expectation was that we would find beams of electrons streaming out along what might be termed the transparent directions of the crystal structure.

The irregularities we had observed in the scattering pattern of the coarse-grained nickel target were very pronounced when the bombarding potential was 75 volts. For this reason our first observations with the single crystal were made at this voltage. We turned the crystal to bring one of the A-azimuths into the plane of the collector, and determined the form of the distribution curve. We were surprised and disappointed to find that it was indistinguishable from what would have been observed had the target been one of ordinary polycrystalline nickel—a simple curve with never a bump or spur from

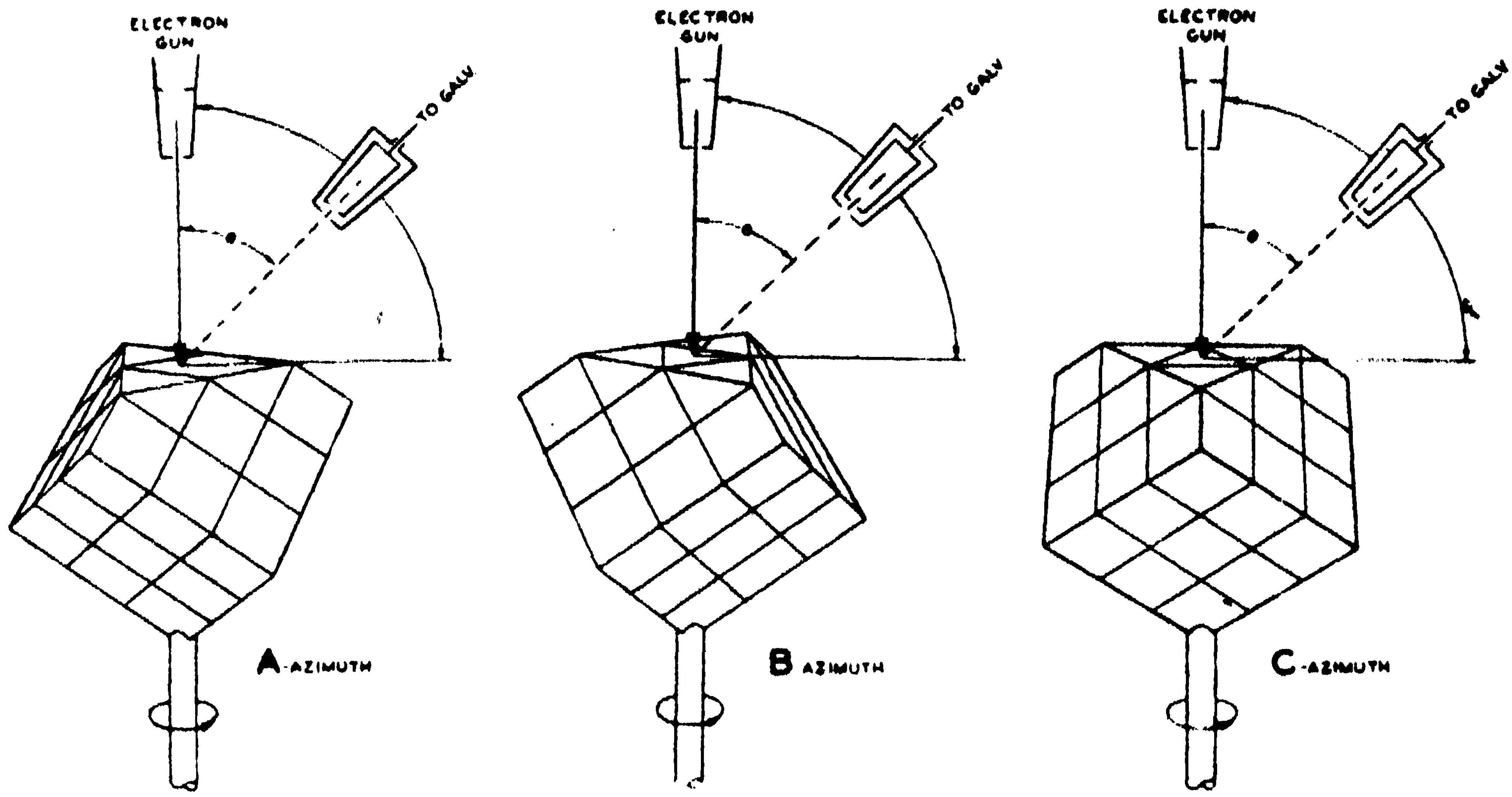


FIG. 3. SCHEMATIC REPRESENTATION OF THE EXPERIMENTAL ARRANGEMENT USED FOR INVESTIGATING ELECTRON SCATTERING FROM A SINGLE CRYSTAL.

one end to the other. The B- and C-azimuths were explored with the same result.

While we were wondering how this could be the tungsten filament which supplied the bombarding electrons burned out, and what with various interruptions and delays it was several months before the damage was repaired and we were able to continue the observations. In the meantime I had had the pleasure and the benefit of attending the Oxford meeting of this association, and of discussing these matters with Dr. Hartree, Professors Born and Franck and one or two others. And when the measurements were resumed a month later we were rather hoping, I think, to find something in the nature of an interference phenomenon. At any rate, we began a systematic study of the distribution curves of each of the principal azimuths, beginning at the lowest bombarding potential at which observations could be made and working upward. And in January, 1927, we came upon the first departure from the simple type of curve. We found that beginning at about 40 volts a slight bump was noticeable in the distribution curve for the A-azimuth, that this bump developed into a strong spur as the voltage was increased, and that after attaining a maximum development at 54 volts, it weakened progressively and disappeared from the curve at about 70 volts.

A family of curves exhibiting this behavior is shown in Fig. 4. These are A-azimuth curves for bombarding potentials 36 to 68 volts. The spur is strongest at 54 volts, and its axis at this voltage lies at colatitude angle $\Theta = 50°$. The curve at the bottom of the figure was obtained by setting the collector in the axis of the spur at maximum development, and then measuring the current to the collector as the crystal was rotated. We find a strong maximum in each of the A-azimuths.

Here at last was our dependence of the intensity of scattering upon crystal direction, and here also was the suggestion of an interference phenomenon, for the shining out of those beams at a particular speed of bombardment is clearly similar to the shining out of a set of Laue beams such as might have been observed had our incident beam been

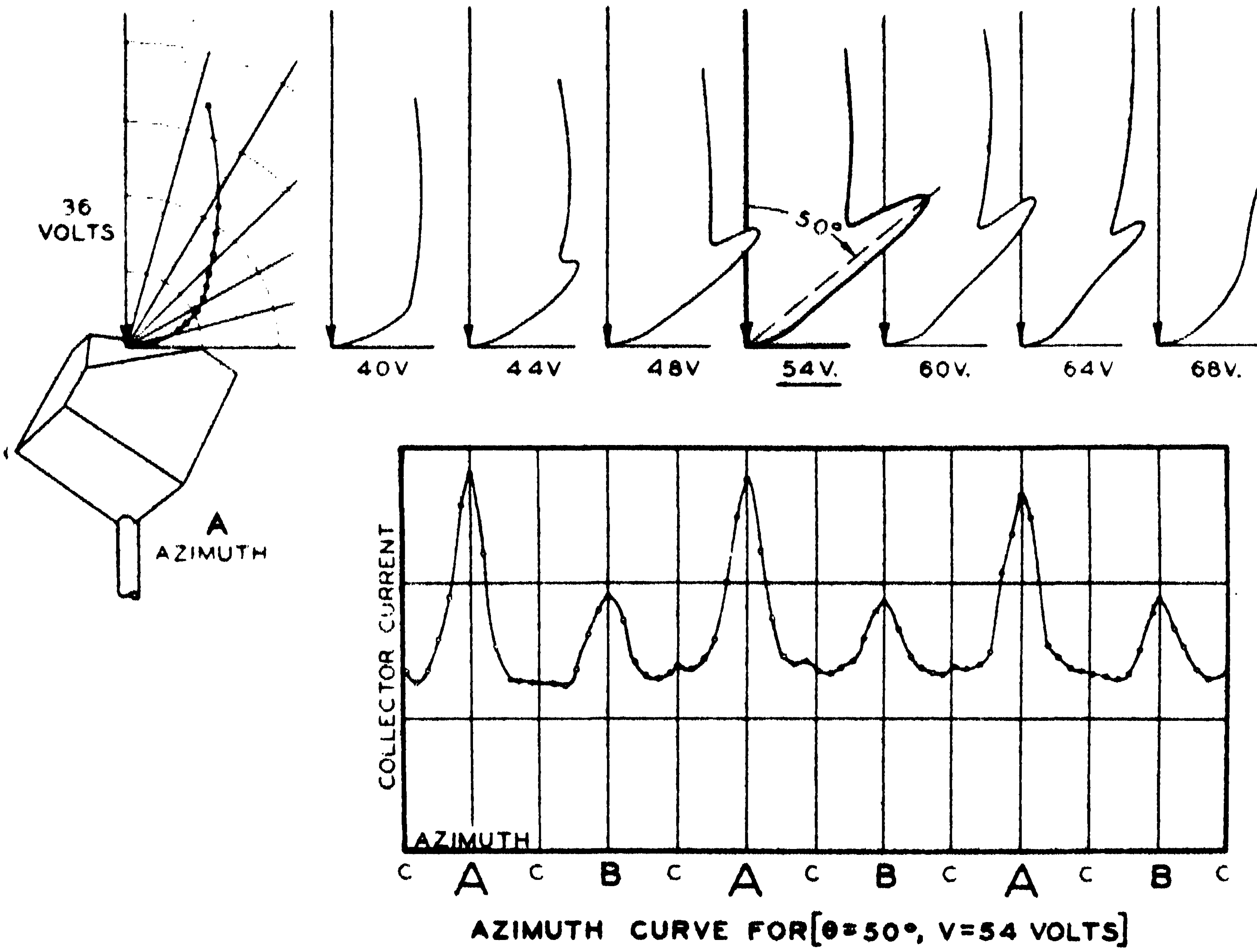


FIG. 4. CURVES SHOWING THE SELECTIVE SCATTERING OF ELECTRONS AT AN ANGLE OF 50° FOR A BOMBARDING POTENTIAL OF 54 VOLTS.

one of monochromatic X-rays of adjustable wave-length. But here the similarity seemed to end, for we found on making the calculations that no one of the important A-azimuth Laue beams lies in the direction $\Theta = 50°$. If the wave-length of an incident beam of X-rays were decreased from some large value, the first set of Laue beams to appear would indeed lie in the A-azimuth—not, however, at $\Theta = 50°$, but at $\Theta = 70°$. And the next set to appear in this azimuth would lie at $\Theta = 44°$.

We were most anxious, of course, to calculate an equivalent wave-length for this electron beam at $\Theta = 50°$ to find if it might agree with the de Broglie wave-length h/mv for electrons of speed corresponding to 54 volts. But the beam does not lie in the direction of regular reflection from any of the important sets of Bragg atom planes of the crystal, and it was impossible, therefore, to follow the usual procedure and to make use of the Bragg formula for this purpose. The Bragg formula is not, however, the only means available for calculating the wave-lengths of Laue beams. It may be shown, for example, that the wave-length of each such beam satisfies the ordinary plane-grating formula of optics with respect to one or another of the plane gratings formed by lines or files of atoms lying in the surface of the crystal. Thus the atoms in the surface of our crystal may be regarded as arranged in lines at right angles to the plane of the A-azimuth. These lines of atoms form a line grating of which the constant is 2.15 A, and the wave-length of every Laue beam appearing in this azimuth satisfies the ordinary plane-grating formula with respect to this grating. The fact that this formula

could be applied in a perfectly definite way to calculate an equivalent wave-length for our beam of electrons, whereas the Bragg formula could not, was not perhaps very good justification for its use, and yet I do not recall that this caused us any great amount of worry. We applied the formula and obtained a wave-length which was, indeed, in very good agreement with the value of h/mv for 54-volt electrons, the values being 1.65 and 1.67 A respectively.

And now I should like to anticipate the conclusion at which we shall shortly arrive—namely, that electrons are indeed scattered as if they were waves—to remark that these waves are appreciably absorbed in traveling only atomic distances in solids, and that, as a consequence, a film of gas on the surface of the crystal acts as an absorbing screen to reduce very materially the intensity of diffraction beams such as shown in Fig. 4. The surface of the crystal was, in fact, heavily coated with gas at the time these first observations were made. The curves shown in Fig. 5 are for this same beam when the crystal is in a gas-free condition—the gas having been removed by heating. The intensity of the beam has been increased by this treatment about fourfold.

We found next a beam in the B-azimuth which is most intense when the bombarding potential is 65 volts, and which lies at $\Theta = 44°$. Again there is no important Laue beam lying in this direction, but again the wave-length of the beam calculated from the plane-grating formula was in good agreement with that calculated from $\lambda = h/mv$—the values being 1.50 and 1.52 A respectively.

The explorations were then extended to 370 volts, and in this range seventeen additional sets of beams upon which measurements could be made were found in the three principal azimuths. The agreement between the wave-length calculated from the grating formula and that given by the de Broglie relation is not so good in all cases as for these first beams, but the disagreement seems to us in no case excessive in view of the difficulty of the measurements. In Fig. 6 we have plotted the results of all the wave-length measurements we have so far made. These include the nineteen measurements just described, and in addition a few others in which the incident beam meets the crystal surface other than normally. What are plotted are observed wave-lengths, those calculated from the grating formula, against theoretical wave-lengths, those calculated from $\lambda = h/mv$. And what we conclude from this diagram is that these quantities are equal within the limits of accuracy of our measurements.

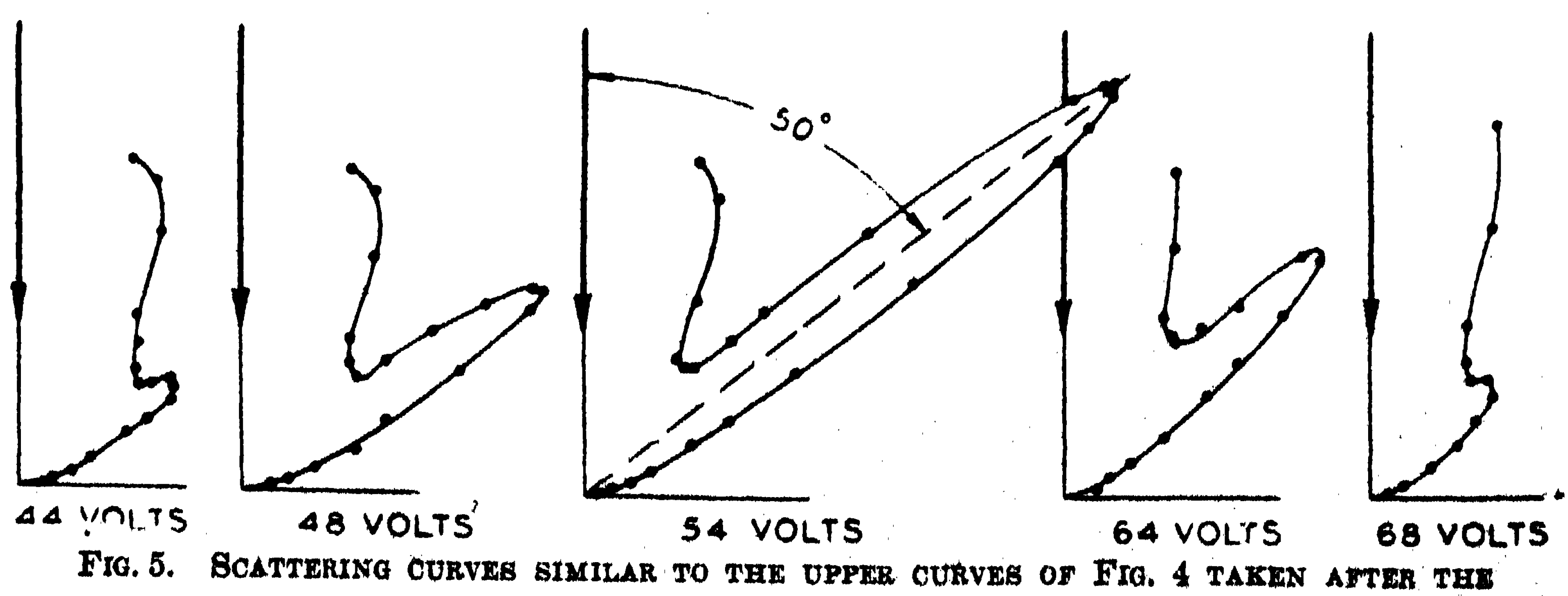


FIG. 5. SCATTERING CURVES SIMILAR TO THE UPPER CURVES OF FIG. 4 TAKEN AFTER THE CRYSTAL SURFACE HAD BEEN FREED FROM ADSORBED GAS BY HEATING.

We have not been concerned in this comparison of wave-lengths with the reason why the directions taken by the electron beams are not the same as those taken by the Laue beams. We have taken the electron beams as we have found them and have calculated their wave-lengths without regard to their law of occurrence. This law is clearly not the same as the law of occurrence of Laue beams, and yet it is evident from an examination of the data that the two laws are in some way related. To illustrate this we display the data in a diagram (Fig. 7) in which we coordinate wave-length and the sine of the colatitude angle Θ. This particular diagram is for the A-azimuth. The crossed circles coordinate the wave-lengths and angles of Laue beams occurring in this azimuth, and the solid dots coordinate the same quantities for the electron beams, the wave-lengths being calculated from the de Broglie formula. The crossed circles representing the Laue beams fall on straight lines through the origin, and these straight lines are the graph of the plane-grating formula for this azimuth, in its various orders. Our first conclusion may be restated by saying that, within the limits of accuracy of our measurements, the solid dots representing the electron beams fall along these same straight lines.

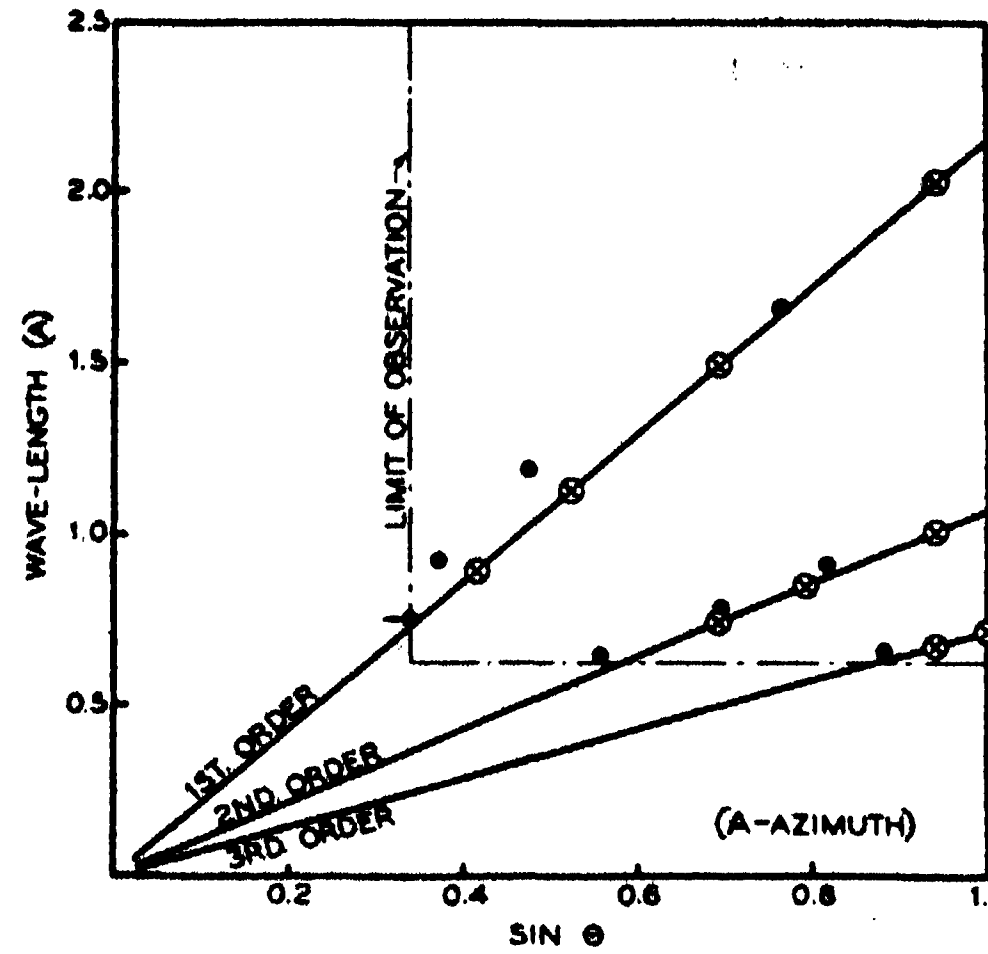


FIG. 7. DIAGRAM CORRELATING THE WAVE-LENGTHS AND ANGLES OF OCCURRENCE OF ELECTRON BEAMS AND OF X-RAY BEAMS IN THE A-AZIMUTH OF THE NICKEL CRYSTAL.

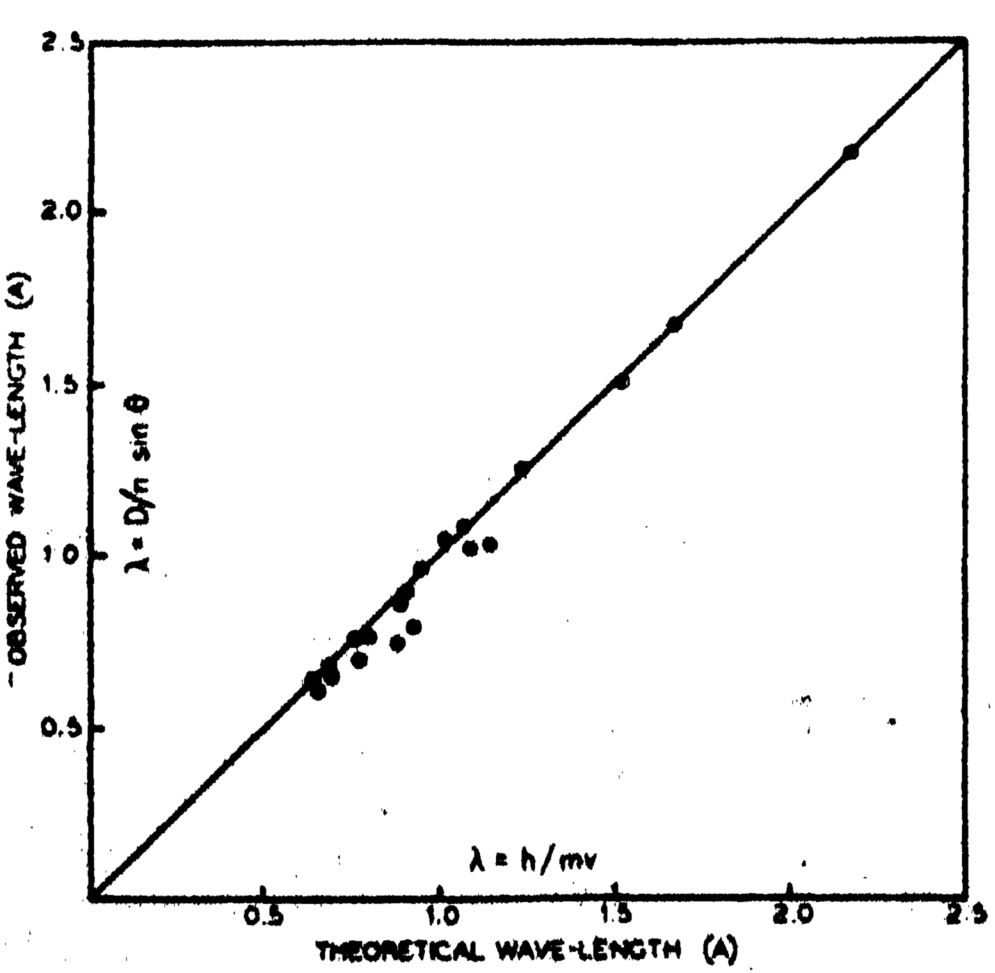


FIG. 6. GRAPHICAL COMPARISON OF ALL EXPERIMENTALLY DETERMINED VALUES OF ELECTRON WAVE-LENGTH WITH THE THEORETICAL VALUES GIVEN BY $\lambda = h/mv$.

What we see represented in Fig. 7 is a certain array of Laue beams, and a certain rather similar array of electron beams. It is not difficult, in fact, to imagine a one to one correspondence between the beams of the two sets. It is as if each electron beam were the companion or analogue of a particular Laue beam, and as if the electron beams were displaced in some systematic way from their Laue beam analogues. In our first report of these results we said that the electron beams occur as the Laue beams would occur if the scale of the crystal were altered by a certain factor in the direction parallel to the incident beam. What we failed to see at the time is that displacements of the type observed—displacements along the plane-grating lines in this figure—would result if there were a refraction of the electrons by the crystal. This suggestion was made by Eckert and also by Bethe. The suggestion is a particularly attractive one as it affords

a justification of the use of the plane-grating formula for calculating wave-lengths.

Our recent efforts have been directed toward finding whether or not this idea that electron waves are refracted in accordance with the same laws as light and X-rays is really tenable. The procedure has been to find whether or not all differences between the occurrences of electron and X-ray beams can be explained by assuming for the crystal an index of refraction which is a function of electron speed or wave-length only. The results so far obtained are not entirely conclusive. There is, however, a fairly strong indication that the question will eventually be answered in the affirmative. I shall have something more to say about this matter of refraction, but for the present I should like to return to a further consideration of the beams.

Having observed the electron analogue of the Laue diffraction beams, it was quite certain that under appropriate conditions we should observe also the analogue of the Bragg reflection beam. There was no possibility of observing this beam with the first arrangement of the apparatus, as the incident beam met the surface normally, and the regularly reflected beam, if it existed, was outside the range of our observations. In a second experimental arrangement with which we are still working, the angle of incidence can be varied from 0° to 90°, and with this we find, as was anticipated, that the incident beam is regularly but selectively reflected; the intensity of the reflected beam is a maximum at certain critical speeds of bombardment, just as the intensity of the Bragg beam is a maximum at certain critical wave-lengths. Curves from which we infer the existence of the regularly reflected beam are shown in Fig. 8.

These are for angles of incidence of 10, 20 and 35 degrees, and for bombarding potentials for which the intensity of the reflected beam is at a maximum. In each of these cases and in every similar case which we have examined the axis of the spur lies accurately in the direction of regular reflection. These observations, unlike the previous ones, were made with no retarding potential between the parts of the collector. Electrons of all speeds were accepted into the inner box, and the reflected beam shows up against this strong background.

The curves in Fig. 8 illustrate the regularity of the reflection. Its selectivity is illustrated by the curve in Fig. 9. What we have plotted here is the intensity of the reflected beam for angle of incidence 10° against the reciprocal of the de Broglie wave-length. The angle of incidence is held constant at 10°, the intensity of the reflected beam is measured for various speeds of bombardment, and these intensities are plotted

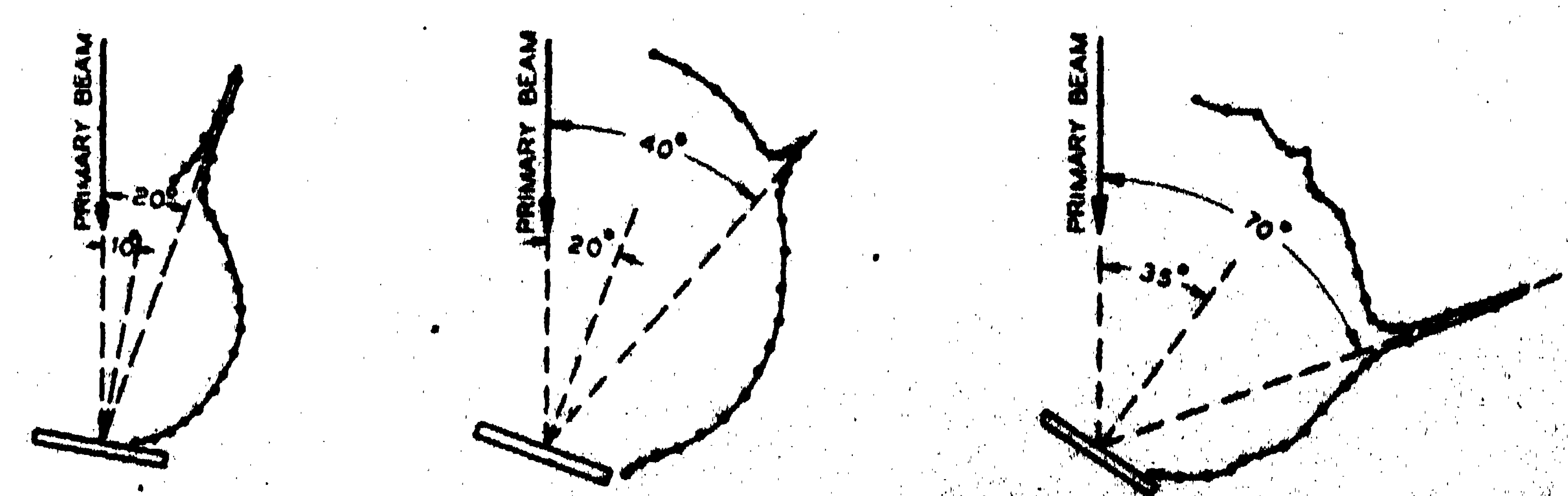


FIG. 8. CURVES SHOWING THE REGULAR REFLECTION OF ELECTRON WAVES FROM A CRYSTAL SURFACE.

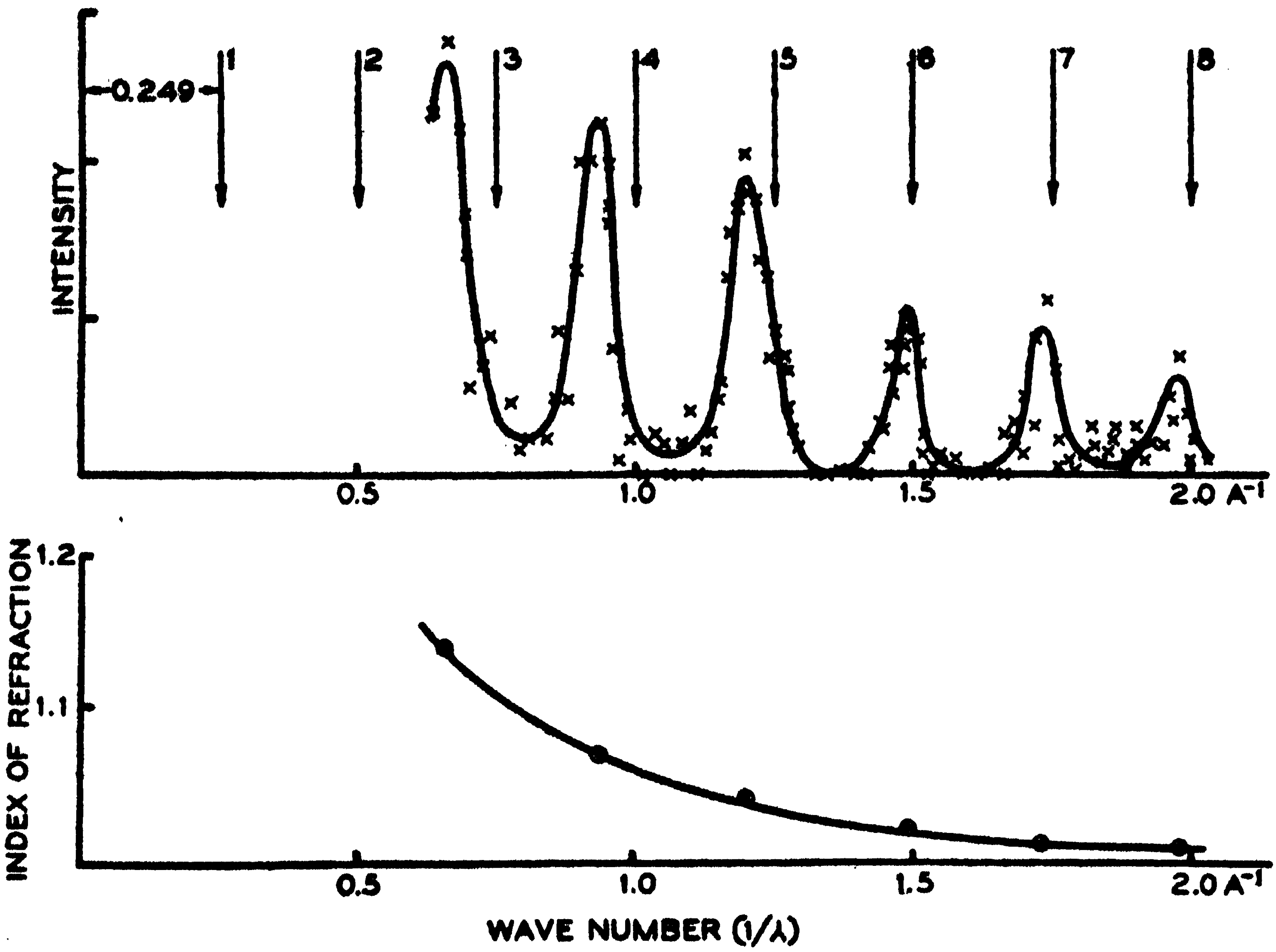


FIG. 9. CURVE SHOWING THE SELECTIVITY OF ELECTRON REFLECTION FOR ANGLE OF INCIDENCE 10°, TOGETHER WITH VALUES OF REFRACTIVE INDEX CALCULATED FROM THIS CURVE.

against the reciprocals of the corresponding wave-length. The equivalent experiment with X-ray could not be made at all conveniently, since with X-rays we do not have available a monochromatic beam of easily adjustable wave-length. It is quite easy, however, to deduce from Bragg's law what would be observed. We find that the corresponding curve for X-rays would be characterized by equally spaced maxima, the distance between successive maxima being 0.249 on our scale of abscissae. The positions or wave-lengths at which these maxima would occur are indicated by the arrows in the figure. If the Bragg law obtained also for de Broglie waves, the maxima in this curve for electrons would occur at these same positions. That they fail to do so is, of course, not surprising. We have seen that the electron diffraction beams fail to conform to the Bragg law, and it would be puzzling, indeed, if this law were found to obtain in the case of the reflection beam. Here again the difference between the electron and X-ray phenomena is such as might result from electron refraction. It is quite easy, in fact, to calculate from the curve in Fig. 9 indices of refraction for electrons of the speeds corresponding to these maxima. The values found are plotted in the lower part of the figure. They decrease regularly from 1.14 to 1.01 as the wave number $1/\lambda$ is increased from 0.6 to 2.0 A^{-1} or as the bombarding potential is increased from 60 to 600 volts.

Now electron refraction is in a way a reasonable and acceptable sort of phenomenon. We know that electrons are accelerated as they pass into a metal, and if we want to regard electrons as particles rather than as waves we may explain the refraction of electrons as

Newton explained the refraction of light on the corpuscular theory. If we prefer waves we think of the change in potential experienced by the electrons on passing into the metal and calculate a change in wave-length either from the de Broglie formula, or by means of the Schroedinger wave equation. Whichever view we take we are led to expect that the index of refraction will be appreciably greater than unity for electrons of low speed, and that it will approach unity according to a certain simple law as the speed is increased. The form of the dispersion curve should, in fact, be much the same as indicated by these results. What we may call the scale factor of the curve is determined by a single parameter—a potential difference characteristic of the metal, which we naturally think to identify with its thermionic work-function. It is somewhat surprising, therefore, that to account for the scale factor of the dispersion curve shown in Fig. 9, we must assume a work-function equivalent to about 18 volts—a quantity much too large to be mistaken for the ordinary thermionic work-function of nickel.

But again the theorist is ready to resolve the riddle. The interesting suggestion has been made by Bethe that the refractive index is determined not by the Richardson work-function, but by the larger absolute work-function which figures in the Fermi-Sommerfeld theory of electrons in metals. Eighteen volts, it appears, is an acceptable value for this latter constant.

And now it is too bad to have to report that the further measurements which we have made of the refractive index confirm the curve shown here only in the region to the right of $1/\lambda = 1$ A^{-1}. In the region to the left the dispersion is much less simple than was indicated by these first results. The dispersion curve in this region is, in fact, highly complicated, as will be seen from Fig. 10, in which we have plotted all values of refractive index obtained in these measurements. What interpretation is to be placed upon these flourishes we do not know. There is a suggestion

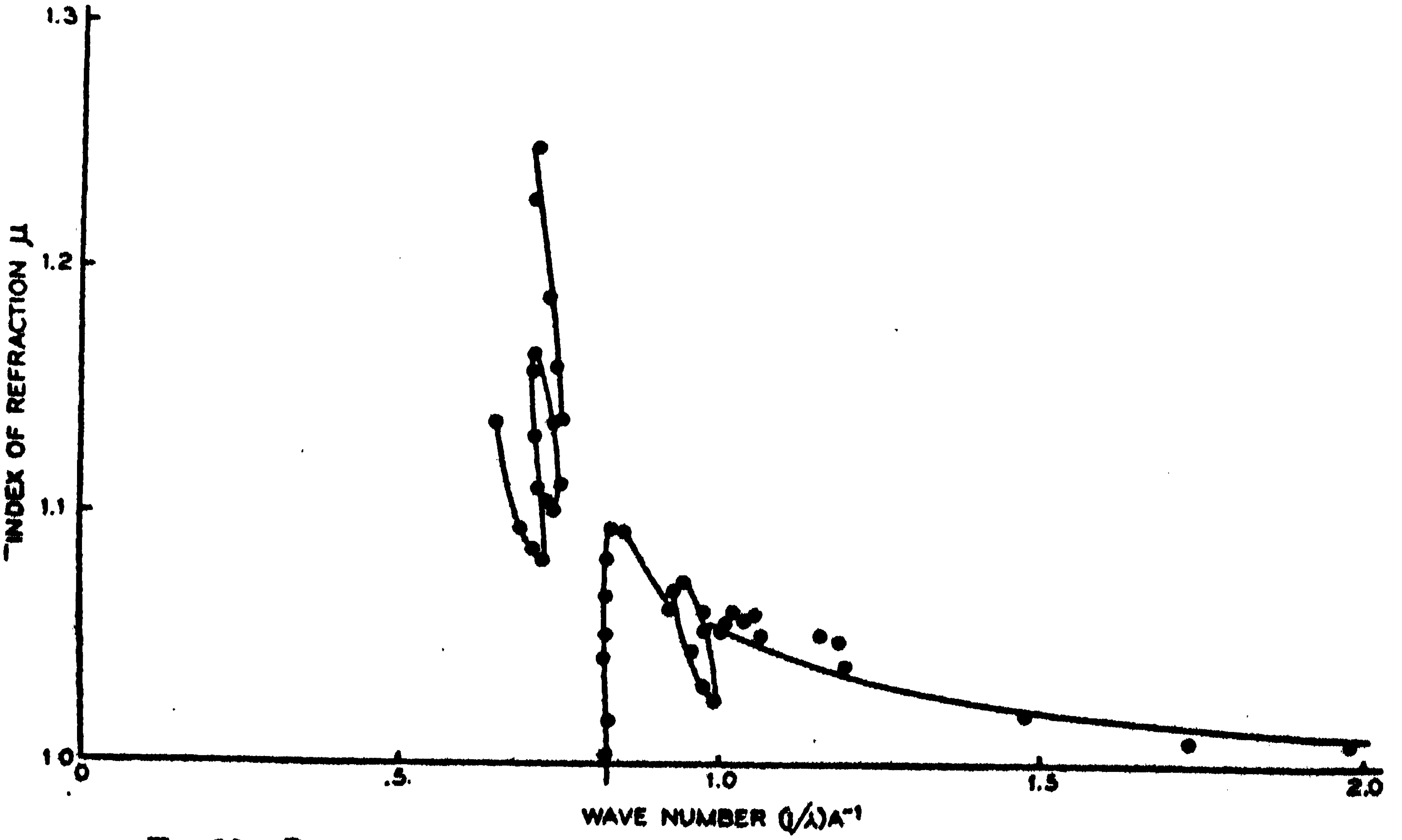


FIG. 10. DISPERSION CURVE OF THE NICKEL CRYSTAL FOR ELECTRON WAVES.

here, of course, of a resonance phenomenon such as that to which we ascribe the anomalous dispersion of light, but oscillators and resonance would appear to have no place in the theory of electron dispersion.

It has been remarked already that for electrons of high speed the index of refraction approaches unity as the speed is increased. At 600 volts the index is about 1.01, and at 1,000 or 2,000 volts it should be equal sensibly to unity. The geometrical differences between electron and X-ray diffraction should, therefore, decrease as the speed of bombardment is increased and should become imperceptible when the bombarding potential is measured in thousands of volts. That this is true is clearly shown by the beautiful experiments which have been reported by Professor G. P. Thomson and his collaborators.

GEOLOGY, ITS STUDY AND RELATIONSHIPS

By Professor BRADFORD WILLARD

DEPARTMENT OF GEOLOGY, BROWN UNIVERSITY

GEOLOGY is earth science. It is less a true science than it is a league of closely related sciences. To the student of geology a broad field of investigation is open. He must master his own chosen realm of study, and must supplement this with many courses in other fields of learning. With the accompanying relationship diagram before us, let us consider what sort of curriculum must be followed if one would become a specialist in geological work.

The beginner usually first makes contact with geology through a course in physiography or physical geography, followed by one in historical geology, that is, earth history. From these as a foundation, his undergraduate studies lead him into fields devoted to the various divisions of geology. Often he is undecided what in earth science appeals most to him, and it is just this "browsing around" during undergraduate days which gives him the opportunity to select a branch for further, concentrated specialization. Following his introductory year, he usually attends a course in mineralogy and crystallography with some petrography and petrology and leading to more advanced courses in petrography or optical mineralogy. These are logical preludes to studies in metallic economic geology, since it is here that training in mineralogy is most applicable. As he continues, he may register in courses in stratigraphy and sedimentation, structural and dynamical geology, prospect-

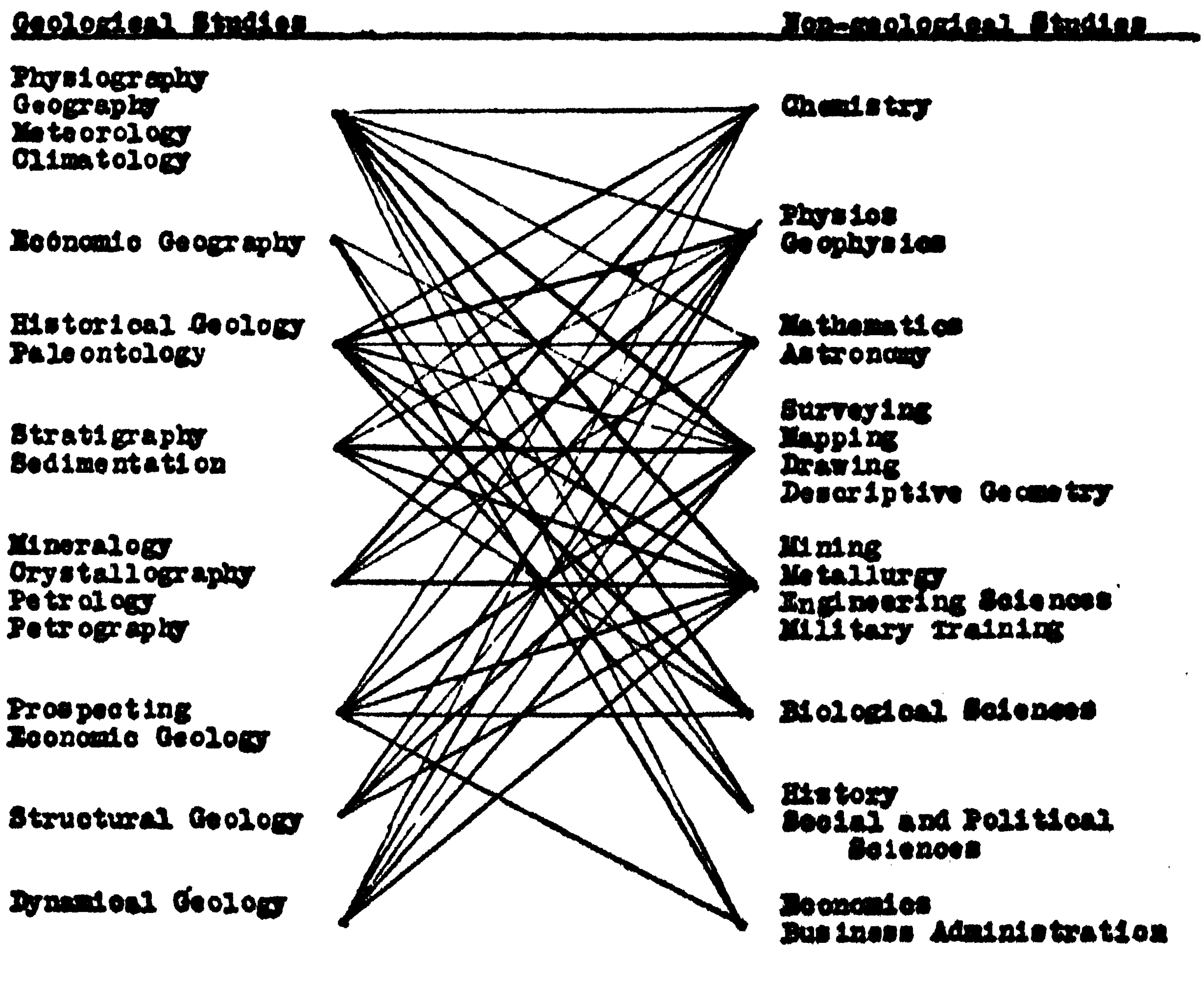


TABLE OF GEOGRAPHICAL RELATIONSHIPS.

ing, paleontology, and so forth; or, if he has a leaning toward a business career, he may specialize in economic geography. By his senior year he is fitted to undertake a simple field problem such as mapping the geology of a small area, solving a problem in physiography or interpreting some bit of rock structure. But if he is to step into remunerative geological work his training should not stop with only undergraduate studies.

Specialized graduate work is now held a necessary preparation for the student of earth science. Seldom to-day can a man with only a bachelor's degree and a few courses in geology to his credit secure geological work, much less aspire to teach in the field. Graduate studies usually lead into some form of specialization. He may make his major mineralogy and petrography. On the other hand, with these subjects as a minor study, he perhaps devotes himself to mastering the principles of economic geology. Advanced physiography and economic geography in conjunction with courses in economics may occupy his graduate years, constituting a "split major." Again, stratigraphy and paleontology offer inducements to the student interested in evolution and earth history and having a liking for biological subjects. Still others find it their preference to carry on, during graduate years, a general advanced course in several branches of geology, this chiefly in the cases of those preparing to teach. In whatever field the graduate may continue, research problems must be undertaken, perhaps as theses, best developed in actual field work in summer schools of geology or, preferably, in regular, off-campus, geological employment.

On completion of graduate work, for what is the newly fledged, would-be geologist suited? His training may be of the best, but he still lacks that most essential of all qualifications of a geologist (omitting the physical)—actual experience in unsupervised application of his understanding of earth phenomena. How may he secure this training? First, there is geological survey work. Such surveys are maintained by the federal and a number of state governments. A more excellent field of training can hardly be found. There is a steady demand for geologists in private enterprises, mining, metallurgy, engineering all requiring their assistance. But such applied geology is not the limit of possibilities. We may also designate certain types of more theoretical work, teaching and research positions and museum employment. Rare indeed is the college or university to-day without at least one geologist on its staff of instruction. Many employ several, usually representing the divisions of physiography, general geology and mineralogy; and the larger institutions retain men in less common branches.

But the scholastic training of a geologist is not confined to the subjects taught by his own department. It would be impossible for him to master these without supplemental work. Can the mineralogist work without chemistry; the paleontologist without biology? Consider briefly what such extra-geological training must be.

Assume that a student has elected to specialize in economic geology. His field lies chiefly along lines associated with mining, and metallurgy, surveying and mapping, engineering methods, plus economics and business administration. He should attend at least elementary courses in as many of these subjects as time will permit him. As a geologist his training must be most complete in mineralogy and petrography, since upon these depends his ability to recognize ores, understand their occurrence and interpret their origin. A study of mineralogy implies a knowledge of con-

siderable chemistry, an ability to "run analyses" of rocks and ores and understand the chemical make-up of minerals. Physics is useful in the application of the laws of optics and light to the operation of the petrographic microscope. A student of economic geology should understand prospecting, for it is the geologist who finds the ores which the mining engineer extracts and the metallurgist refines. Structural and dynamical geology must be added. Through the former the geologist understands the "lay" of the rocks underground. Deep-buried structures are more readily understood if the student be trained in descriptive geometry. Dynamical geology teaches him physical and chemical changes which have metamorphosed the rocks, often resulting in the formation of ore bodies. Here again a knowledge of physics is needed in appreciating the mechanical forces involved in metamorphism. Such knowledge is but a step removed from geophysics with mathematics an assumed adjunct. A large proportion of the economic geology of to-day is concerned with non-metallic products, such as petroleum and natural gas, coal and cement. The search for these, particularly the petroleum and natural gas, demands an understanding of stratigraphy and sedimentation in order that the worker may interpret the origin of bedded deposits of rocks and the occurrence of their included economic products. In oil work, incidentally, ability to survey and map is even more helpful than in most geological field work. It is an essential part of the training of a geologist whatever his specialty. Paleontology, chiefly micropaleontology, becomes of prime importance in studying the minute organisms whose fossil remains are to-day so largely used as guides to oil-bearing strata.

But suppose a student chooses paleontology as his field of work. Paleontology takes into consideration the biology of extinct plants and animals, their evolution and their relation to living forms. It teaches of the former distribution of organisms and allows glimpses of ancient climatic conditions. The student of paleontology should include among his courses zoology, botany, comparative anatomy, embryology, evolution and anthropology; a smattering of bacteriology and archeology will do no harm. The paleontologist is usually most concerned with earth history, organic evolution and problems of stratigraphy, the last since it is from the stratified rocks that fossils are collected; while, conversely, the kinds of organic remains present are usually a clue to the conditions under which the enclosing strata originated. For such applications he must know some chemistry and physics. Geophysics enters his line of vision since it is tied up with the great earth movements of the past and the development of earth structures and features through the ages. The paleontologist as a student of earth history meets the astronomer half-way in that their respective investigations dovetail one another in accounting for the origin of the earth.

These are but two examples of the type of geological and extra-geological studies a student in the field of earth science should pursue. It might be emphasized that no matter in what division he may concentrate, there are at least three essential non-scientific studies to be added. First, he should be able to make a respectable, if not artistic freehand sketch and know enough mechanical drawing to teach him familiarity with the drawing board and instruments. Second, a reading knowledge of foreign languages is not to be omitted from his training. Witness the established requirements of students who are candidates for the doctor's degree in any science. They must have at least a good

grounding in French and German. Spanish and Italian are no superficial additions to the list. Finally, and perhaps most essential of all three and yet probably the most neglected, is the ability to prepare a written report in clear, concise, scientific English.

So much for the training received by a geologist in his own and supplementary fields of study. What of the converse? Can a knowledge of geology be of value to those who chose other fields of investigation, scientific or otherwise? Consider a few examples.

What of the chemist? Is it of any value to him to know the origin, occurrence and economic value of many naturally occurring substances with which he often works? Here opens the broad vista of geochemistry. The geophysicist must, for his highly specialized investigations, be trained in geology and physics. The economist better understands the distribution of raw products through a course in ecomonic geography. Meteorology and climatology explain how weather and climate influence business conditions. Nor can he afford to ignore the world's leading regions of great mineral wealth, made known through economic geology. Turn to the engineering profession. Of mining and metallurgy enough has already been said. What civil engineer dares be oblivious to bed-rock conditions when selecting a cite for a huge dam, in excavating for a foundation, driving a tunnel or sinking a shaft? His training in the strength of materials is certainly not hampered if he knows the mineral composition and weather-resisting qualities of common building stones. The military engineer must apply geology. Its value was emphasized only too clearly in France. An army needs potable water. Topography is one of the great considerations in a military operation. Where, too, is the unit which, under fire or otherwise, can "dig in" into solid rock? A knowledge of subsurface conditions is indispensable to mining and sapping. Furthermore, can the surveyor do better than understand the origin and character of the rocks beneath and the physiographic history of the terraine which he maps? Then there is the historian. Here is one who studies the *few score* centuries of human development. The historical geologist goes back *millions* of centuries. Wells's treatment in "The Outline of History" is an example which may be taken seriously by the all too superficial historian. Let him learn of the prehistoric development of man as a prelude to understanding the historic. In like manner, historical geology forms an excellent supplementary course for one working in social and political science; and through physiography he interests himself in the environment and background of man's development and behavior. Finally, what of the biologist? Let him keep in mind both the axiom, "Know well the present e'er crossing the threshold of the past," and its equally true converse. The zoologist and botanist draw "trees" of evolution, yet see only the tips of the twigs. Train them in paleontology, and figuratively and literally they will dig down to the roots, first exposing the twigs, then the small branches, next the larger limbs and finally the trunk itself. Paleontology is "the documentary evidence of evolution." Teach the student of biology the lore of the fossils, and his comparative anatomy, embryology and above all organic evolution will bear fruit a hundredfold more bountifully.

Why study geology? With the depletion of our larger deposits of mineral wealth, it is to the geologist that the world must turn to discover lesser but increasingly valuable sources of world supply of those commodities without

which our civilization can not hope to survive. Probably the geologist more than any other scientist secures the widest outlook on nature through studies in many fields. A specialist in a branch of earth science, he is also something of a chemist, physicist, economist, biologist and engineer—in short is trained in general science. His work takes him to all sorts of out-of-the-way corners of the earth. He visits distant lands, sees unusual sights and mingles with strange peoples. His work brings him into contact with men busied with other sciences. Conversely, specialists in other sciences, through a little geology, broaden their appreciation of their own fields. Through geology comes a linking together of many subjects, a meeting of trained minds on a common ground. Geology becomes a clearing house for the exchange of ideas and scientific thought leading toward the solution of problems of mutual interest. Furthermore, its study helps eliminate some of those errors in any field all too often committed through ignorance of topics of common knowledge in another.

As astronomy teaches of vast distances, so geology tells of inconceivable lapses of time. More than any other scientist, the student of the composition and behavior of our earth appreciates the work of nature in forming and developing that world. The paleontologist, trained in biology as well as geology and with a deep insight into organic evolution, sees in the stream of life man's "long-continued, slow progress." Lyell, shortly after 1859, began to add geological facts to the evidence gathered in support of organic evolution. Since then geology has taken a leading part in proving and explaining the story of the development of living forms. If these seventy-odd years have produced such results as now we see, what may we expect from the future study of rocks? With these possibilities of coordination of different sciences, cooperation of scientists in related fields, discovery of economic products in mineral wealth, interpretation of the past and above all the evolution plus a hint of the future of the race, need the study of geology lack recruits to its ranks?

ANTIVIRUS VACCINES IN SURGERY

By Dr. STÉPHANE EPSTEIN[1]

It is generally agreed that surgery has made enormous progress during the last fifty years. Operatory technique has itself, of course, made vast strides, and certain adjuncts, such as adrenalin, allow a surgeon to operate with a precision and a rapidity that were formerly unknown. New instruments and the extended use of electricity beyond mere motive power have indicated a new path for surgery. But the chief characteristic of modern surgery as compared with that of the first two quarters of the last century is the marked diminution in deaths resulting from operations. When one reads of the manner in which patients formerly were treated after an operation one asks oneself how a single one could possibly have escaped infection. Hospital rot was worse than any wound and an operation was usually equivalent to a death sentence. Contamination was conveyed by instruments, by the hands of the surgeon or his assistants, by dressings, by the general surroundings

[1] Translated from the French by R. Vivé Bazely.

and lastly by the curative methods themselves. It is not so long ago that cobwebs were applied to cuts and urine to abscesses.

The speeches and pamphlets in commemoration of Lord Lister's centenary give a terrible picture of septicemia following on operations. The average mortality was 40 to 50 per cent., and surgeons only operated when no other issue was possible, and in the case of abscesses waited for them to burst rather than use the lancet. Lister changed all that, and his methods may be regarded as the first stage in the struggle against infection. Sir St. Clair Thompson has rightly remarked that the Lister process has saved more lives than the great military heroes of all ages have managed to destroy.

From the moment when everything that touches a wound was disinfected and the deadly germs destroyed, post-operatory mortality fell to 3 per cent. and a rapid cure was assured.

It was, however, observed that antiseptics applied to wounds killed not only pathogenic agents but even the living cells, with the result that scars were ugly and irregular. An effort, therefore, was made to modify the system without abandoning the principles upon which antisepsis is based. It was argued that, if, instead of destroying the germs, they could be prevented from entering the wound during an operation, nature would do the rest. Sterilization replaced disinfection and heat antiseptics. If operating theater, instruments, hands, dressings, the operating field itself were all sterilized, the bacilli that might be in the wound would lack a favorable ground and a cure would be brought about spontaneously.

Here is then the second stage. The aseptic method has replaced the antiseptic and is supreme in all forms of infection.

Both methods arise out of Pasteur's discoveries which made Lister's possible; without the discovery of the principles of fermentation, sterilization would have remained in the fourth dimension.

But the process of healing was still obscure, and, thanks to Metchnikoff's discovery of the rôle played by phagocytes in the struggle against deadly germs, the necessity of two methods in avoiding infection was perceived—direct destruction of micro-organisms causing necrosis of the living tissues and isolation of the parts liable to infection in order to allow the phagocytes usefully to perform their task. The aseptic method only answers these requirements partially: specific dressings seem to be the next stage after antiseptics and aseptics in the struggle against infection.

In the majority of infected wounds and even in a large number of diseases, we find that two microbes predominate, streptococci and staphylococci.

At first sight both appear peaceable, resembling little regularly formed motionless heaps which take the shape of clusters or chains and are easily colored. But under this benign appearance they are disconcertingly active. The diseases which they occasion or in which they play the leading part are without number. They are to be found in boils, whitlows, otitis, acne, osteomyelitis (inflammation of the bone and bone marrow), in the skin complaints of infants (pyodermitis), inflammations of the eyelid (blepharitis), phlegmons, conjunctivitis, mastitis, purulent pleurisy, puerperal fevers, etc., etc., and in most wounds and infected burns. One can, in fact, speak of two categories of disease, streptococcic and staphylococcic.

Having ascertained the determining rôle of streptococci and staphylococci in septicemia we had to find out whether there was a means of combating these two pathogenic agents in a specific man-

ner. We thought instinctively of serotherapy and curative vaccination, but immediately a serious obstacle arose; in the case of laboratory animals hypodermic or intraperitoneal injections were found inoperative and it was difficult to think of vaccination when experimental infection was impossible. Nevertheless, human beings derived benefit occasionally from anti-streptococcic and anti-staphylococcic immunization. The results were meager, varying and often deficient; still there were results.

Dr. Besredka, to whom we owe so many magnificent discoveries, studied systematically the problem of staphylococci and streptococci. In examining the mechanism of infection and immunity he noticed that in certain microbial affections the entire organism participates in the defense of the integrity of our "self"; in others immunity is a local phenomenon, that is to say that certain tissues have a special predilection for certain microbes, and if there is no contact between the elective tissue and the microbe, the latter can neither multiply nor elaborate its toxins.

Dr. Besredka asked himself at this juncture whether there was not a relationship between streptococci, staphylococci and bacteridia, that is to say that an important rôle must be assigned to the epidermis in the mechanism of infection, and at first sight this seemed little likely.

There is no organ or tissue which does not offer a wide hospitality to streptococci and staphylococci. Lungs, pleura, joints, kidneys and the bone marrow are amply supplied with them in the event of numerous ailments. But even in a state of perfect health we harbor quantities on the surface of the skin, around the hair and in the ocular, nasal, tonsillar and buccal mucosities. They live on us and with us as inoffensive and peaceable parasites. But their appearance is deceptive; they are on the watch for the slightest infraction, the smallest break of continuity, the most insignificant entry through our protecting teguments of skin and mucosae. A slight traumatism, an intercurrent infection, an inferior state of defense, and the streptococci and staphylococci rush in by the breach, causing carbuncles and anthrax which degenerate into lymphangitis, adenitis and phlegmons, and may even be the cause of osteomyelitis, endocarditis, purulent pleurisy. Carried through the lymphatic ducts they make an onslaught on the phagocytes. If they are overcome and digested, a mild and temporary affection ensues. But if the streptococci and staphylococci gain the victory, they rapidly attack the general system, penetrating the organs and provoking the above-mentioned diseases. Once established, these undesirable guests are dislodged with difficulty. Sometimes they remain dormant and there is nothing to indicate their presence. But their slumber is light and the slightest change in the general state of health is sufficient to arouse their activities.

From the foregoing it is seen that the skin is the tissue affected by streptococci and staphylococci, and that it is a question of rendering them innocuous in their very abode and even of pursuing them along the lymphatic ducts.

The Pasteur school quite naturally looked primarily to serotherapy and vaccinotherapy in introducing into the affected organism either a serum containing elements capable of destroying the pathogenic agents or a vaccine which would allow the cells to defend themselves against the microbial invasion. But the theory of local immunity did not then exist. In consequence serums and vaccines were simply injected according to the habitual method. The results of serotherapy as practiced on laboratory animals were plainly negative.

It was suggested as an explanation that rabbits are incapable of sufficient resistance. This, however, could not be said of human beings, who notwithstanding did not derive any more benefit from anti-staphylococcic and anti-streptococcic serotherapy; after the introduction of the serum into a blood channel, there was not the smallest trace of "antibody." In conformity with the doctrine of Almroth Wright (one of Pasteur's most remarkable pupils, who believed that the intramuscular channel was superior to the subcutaneous and the intravenous to the intramuscular), serums were abandoned and anti-streptococcic and anti-staphylococcic vaccines were injected into the veins. The result once more was negative.

What was the explanation, however, of the fact that the injection when made in the muscles produced a slight effect, was more pronounced when subcutaneous and only attained its full form when it did not penetrate the epidermis?

Contrary to Wright's theory, the more one kept to the surface the greater the effect of the vaccine, and the deeper one went, the less it became, until the diminishing point was reached when the injection was made in the vein.

If one admits, however, that the epidermis is the organ of predilection of streptococci and staphylococci, one finds an explanation for the above-mentioned phenomena, and one understands at the same time that the reason why subcutaneous punctures failed to produce any effect was that it is almost impossible not to penetrate the skin, and because the puncture produced a channel forming a connection between the epidermis and the spot where the syringe had deposited the vaccine. By making the tiniest punctures, almost a scarification such as is practiced in anti-smallpox vaccination, one gives the vaccine its maximum efficacy. A rabbit treated in this manner was able twenty-four hours later to support with impunity an injection of living microbes, whereas others, not vaccinated or vaccinated with intramuscular or intravenous injections, sickened and died if the dose was sufficiently strong. In an animal thus vaccinated and refractory to streptococcic or staphylococcic infection no "antibody" was observed.

This strange phenomenon led on inevitably to the question whether in the case in point it is really the microbial body that vaccinates or something else of which it is simply the vehicle. The problem became still more disquieting when it was seen that there is no need to inject the vaccine; a simple bandage applied to the stomach after depilation or shaving was sufficient to immunize the animal.

With this idea in view a new experiment was attempted. A rabbit was vaccinated without the help of any microbial bodies by the simple application of their soluble products, in other words, juice. When we prepare an apple jelly, we reject skin, pulp, pips, in fact, everything that is not soluble. We proceed in exactly the same way with our streptococci and staphylococci. We allow our culture to stand for eight to ten days in order to disgorge the microbes, after which we strain it through a filter which retains the microbial corpses, and lastly we heat the juice, or scientifically speaking the filtrate, during half an hour at 100° C. We obtain in this manner a clear yellowish liquid, absolutely atoxic and possessing remarkable vaccinatory qualities. And yet the filtrate we have obtained does not differ outwardly from any other cultural broth. In fact, if we were to place in our filtrate the bacilli of typhoid, cholera, dysentery, ague or any other cultivable microbe, they would flourish extremely well. The contrary would be the case if we introduced

streptococci or staphylococci. In an environment from which nevertheless they issued, these germs remained sterile. Just as the minotaur devoured its own children, so this culture nourishes all but its own progeny. A bandage soaked in a streptococci or staphylococci filtrate and placed on the freshly shaved stomach of a rabbit renders it at the end of twenty-four hours refractory to all streptococci or staphylococci. In order to explain the properties of this filtrate one must suppose that together with the virulent substance fixed solidly on the microbial body, there is another substance, an antivirus, which becomes detached from the streptococcus if one allows it to mature. But whereas the virus is destroyed by heat, the antivirus is "thermostable," resisting a temperature not exceeding 100° C. The process is thus perfectly clear. By allowing the cultures to mature we detach all the soluble products which mingle with the environment; by filtration we eliminate the insoluble elements and finally by the application of heat we destroy the virulent elements, leaving a substance of antivirus. And as we have seen that the liquid thus obtained prevents the development of the microbe of which it is the issue, its action appears entirely logical. Applied to an infected area, the antivirus isolates the focus, as in a fire, with an impenetrable rampart; the surroundings are effectively protected and the firemen or phagocytes, arch enemies of microbes, easily overcome the bacilli thus deprived of all nourishment and means of development. It is important to see that the bandages extend beyond the infected area. If in the case of a rabbit we restrict the application to a certain spot we vaccinate that and nothing more. On the other hand, by enveloping it in bandages soaked in antivirus we attain the lymphatic ducts and the entire body is protected. We see, therefore, how a purely local protection can be converted into general immunization. Practical application of this observance has given excellent results in carbuncular troubles which have a tendency to recur in the same place. By covering as large an area as possible with an antivirus dressing we succeed in vaccinating organs or entire regions and in avoiding a relapse over a period of several months. It is of the greatest importance to be perfectly certain of the identity of the microbe before using the antivirus, otherwise the bandage will do as much harm as it should do good. Thus, for example, if we use a staphylococcic instead of a streptococcic antivirus, not only will there be no curative action but on the contrary a development of the pathogenic agent. Instead of isolating the fire, we shall be feeding it; instead of extinguishing the flames with water, we shall be adding oxygen to them.

These laboratory experiments have been confirmed by clinical practice. The rapidity with which infected wounds "clean up," the rapid disappearance of suppuration, the steady fall in temperature and the certainty of a cure are often amazing.

The characteristic of dressings or specific instillations is the speedy disappearance of pain that not even morphia can relieve. We have had under observation an aural carbuncle of normal size which was exceptionally painful: ten minutes after the application of an antivirus the patient only experienced a certain itching and at the end of an hour we were able to examine the ear without causing the slightest discomfort. A complete cure was effected in six days.

On another occasion we examined a carbuncle on the calf of the leg that was

so deep that the practitioner diagnosed it as osteomyelitis.

Forty-eight hours after an application of an antivirus there was no more suppuration, and the wound, now clean and healthy, began to close.

A different case was that of a patient who had suffered for eight years from chronic conjunctivitis; he had seen many ophthalmic surgeons and their prescriptions filled a small volume. The secretions revealed on analysis the presence of staphylococci. We instilled two grams of antivirus into the lacrymal cavity. After five days' treatment the secretions became sterile and a cure followed five days later. We kept the patient under observation during five months without noticing the slightest relapse.

But it is in cases of puerperal affections that these specific dressings have saved hundreds of lives. One knows in these maladies how painful, precarious and wellnigh useless are surgical interventions. The antivirus treatment of puerperal complaints has an enormous advantage in being preventive. In the event of a difficult or even normal confinement being followed by a suspicious rise in temperature a bandage is immediately applied; yards of sterilized gauze, soaked in antivirus prepared from streptococci obtained from the patient, fill up all the infected cavities, and it is extremely rare that on the fourth day the temperature has not fallen to normal.

Dr. Levy-Solal, of the Maternity Hospital of St.-Antoine, has employed this method in current practice; and wherever it has been used in time there has not been a single failure.

Antivirus vaccines are beginning to find their way into surgery.

The sterilization of operating area, instruments and bandages, the most scrupulous washing of hands are often insufficient to prevent the intrusion of germs from a direction far removed from the patient. But if, after sterilization, hands, instruments, bandages, the operating field itself as well as its surroundings are washed or saturated with the antivirus, the undesirable germs become innocuous, and septicemia is avoided, thus insuring a rapid recovery.

In addition to purely local applications the antivirus treatment has been found efficacious in deep-seated streptococcic and staphylococcic affections. Intrapleural and even intravenous injections have given unexpected results in the treatment of pleuritic complaints, endocarditis and pleurisy.

So far antivirus has only been used in streptococcic and staphylococcic affections. Nevertheless, vaccine-cultures are now being prepared from other microbes such as colon bacilli, *B. pyocyaneus*, etc.

Certain German bacteriologists go so far as to attest that immunity from typhoid fever can be secured by simply applying compresses.

But the day that we find the means of procuring the antivirus of all microbes, we shall enter a domain of boundless possibilities.

And the day is not far off—nearer, perhaps, than we think—when we shall be able to filtrate the Koch bacillus, and thereby heal tuberculous sores with the same rapidity and certainty with which we now heal streptococcic and staphylococcic septicemia.

EUROPE AND THE POWER MAP

By Professor W. O. BLANCHARD
UNIVERSITY OF ILLINOIS

Europe, the Industrial Continent

Modern industry originated in Europe and that continent remains to-day the world's greatest workshop. This statement is true whether the ranking be based upon the value of the output or upon the proportion of the working population so employed. Even among individual *nations*, not *continents*, while the value of the output of the manufactures by the United States is larger than that of any other country, there is no part of the world where people are so dependent upon industry for a livelihood as in the countries of northwestern Europe.

Various factors are responsible for this supremacy of European industry. One of the most important is the possession of vast quantities of mechanical energy. Cheap power is as fundamental in modern manufacturing as were the skilled artisans in the old handicraft days. Of the power resources which motivate world industry only three are of importance—coal, water-power and petroleum. Of the world production of these in 1927, Europe accounted for 49 per cent. of the coal, 46.7 per cent. of the water-power and 8.4 per cent. of the petroleum—figures of great significance considering that that continent contains only about 7 per cent. of the land area and 30 per cent. of the population of the world.

Evaluation of Power Resources

In attempting to evaluate the importance of these various energy supplies one is confronted with a puzzling variety of units used in their measurement. Obviously "barrels" of petroleum can not be directly compared with "horse-power" of waterfalls or with "tons" of coal produced. Since "tons" of coal are the most familiar it would be convenient to express the quantity of petroleum or the number of horse-power developed in terms of the amount of coal which, when burned, would deliver an equivalent amount of power.

On the average it has been estimated that 5.4 short tons of bituminous coal or 2.68 barrels of petroleum[1] consumed in the average power plant will deliver a horse-power for a year. Likewise a ton of lignite is considered to be equivalent to 2/9 of a ton of bituminous coal. Using these conversion factors and applying them to the production of coal, water-power and petroleum, it becomes possible to view the various parts of the world in true perspective from the standpoint of their power production.

Table I, showing the production of power in terms of coal of the various continents in 1927, indicates the dominant position of North America and Europe. These two account for about 90 per cent. of the world total. The United States alone produces almost one half (48.5 per cent.) and Europe contributes about two fifths (41.8 per cent.) of the whole.

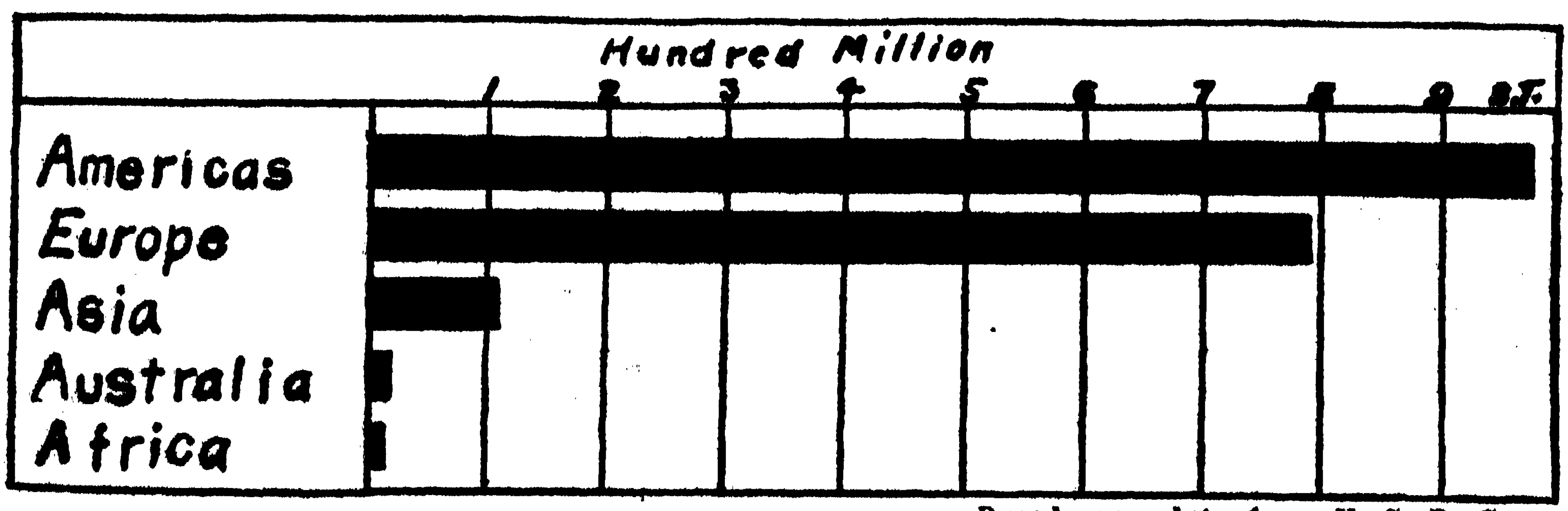
In Fig. 1 we have the same data plotted on the basis of the character of the energy produced rather than the regional distribution. This shows the

[1] U. S. D. C. Yearbook, 1926, Vol. I, p. 262.

TABLE I

MECHANICAL POWER IN EUROPE REDUCED TO COAL EQUIVALENT

	Coal and lignite in terms of s. t. of coal	Petrol. in terms of s. t. of coal	Water-power in terms of coal	Total coal equiv. in s. t.
Albania	....	....	5,400	5,400
Austria	897,600	....	1,755,000	2,652,600
Belgium	27,852,000	....	3,780	27,855,780
Bulgaria	352,000	....	97,200	449,200
Czechoslovakia	20,553,500	35,714	837,000	21,426,214
Denmark	....	....	59,400	59,400
Esthonia	....	....	91,530	91,530
Finland	....	....	1,188,000	1,188,000
France (including Saar)	71,870,700	113,000	10,800,000	82,783,700
Germany	194,088,400	160,000	5,940,000	200,188,400
Greece	29,700	....	43,200	72,900
Hungary	2,333,100	....	16,200	2,349,300
Irish Free State	....	....	....	....
Italy	526,900	10,714	12,420,000	12,957,614
Jugoslavia	1,076,900	....	972,000	2,048,900
Latvia, Lithuania	....	....	27,000	27,000
Netherlands	9,566,700	....	810	9,567,510
Norway (including Spitzbergen)	440,000	....	10,260,000	10,700,000
Poland	39,342,600	1,391,429	486,000	41,220,029
Portugal	138,600	....	54,000	192,600
Roumania	984,500	5,528,571	162,000	6,675,071
Russia	28,927,800	14,986,000	1,485,000	4,398,800
Spain	6,612,100	....	5,400,000	12,012,100
Sweden	290,400	....	7,290,000	7,580,400
Switzerland	....	....	9,990,000	9,990,000
United Kingdom	272,873,700	714	1,350,000	274,224,414
Total	678,757,200	22,225,428	70,733,530	771,716,862

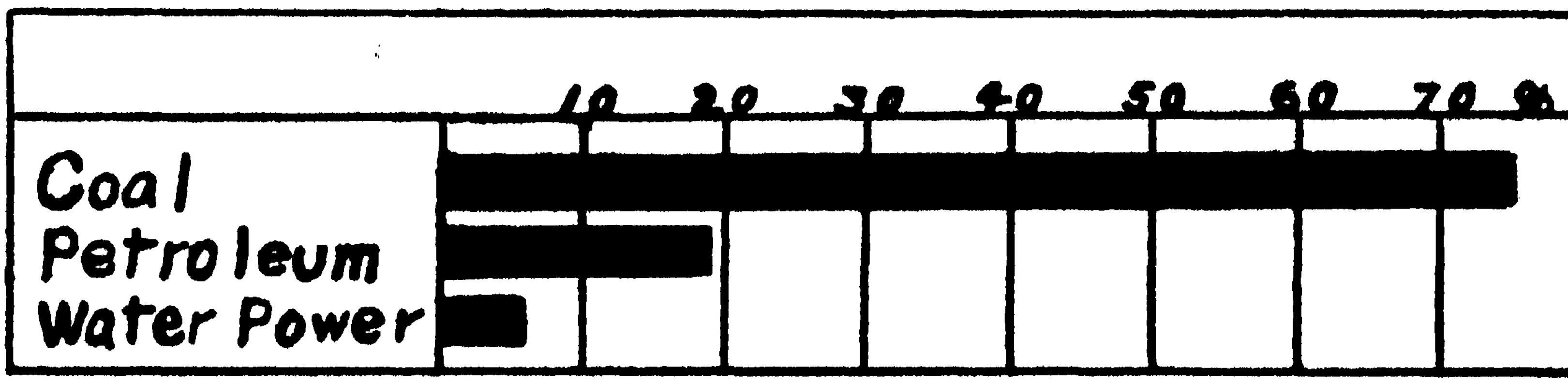


Based upon data from U. S. D. C.

FIG. 1. POWER PRODUCTION OF THE WORLD IN TERMS OF COAL IN 1927. PRACTICALLY ALL OF THE TONNAGE CREDITED TO "AMERICAS" IS CONTRIBUTED BY NORTH AMERICA. THE UNITED STATES ALONE ACCOUNTED FOR OVER 90 PER CENT. OF THE TOTAL FOR BOTH THE AMERICAS.

all-important rôle played by coal. It is responsible for 75 per cent. of all power, while petroleum and water-power contribute 19 per cent. and 16 per cent. respectively.

the much-advertised water-power of Switzerland. The coal of Spitzbergen widely heralded as solving the fuel problem of Norway actually contributes but 5 per cent. of the latter's power. It is interesting to note that even within the "water-power belt" such countries as Spain, Jugoslavia and Austria, whose waterfalls are commonly considered as practically the chief reliance, actually depend for about one half of their power upon their coal mines.



Based upon data from U. S. D. C.

FIG. 2. WORLD PRODUCTION OF POWER IN TERMS OF COAL IN 1927 ARRANGED BY SOURCES.

Fig. 2 shows the power distribution in 1925–26[2] for the countries of Europe. The dominant position of the great coal-producing countries—Great Britain, Germany and France—is striking. These three countries comprise only one eighth of the area but account for almost two thirds of the total power and two thirds of the total manufactures of all Europe. In general it will be noted that the zone of large power production runs through central Europe from England to Russia—the belt in which coal provides the motivating force. Flanking this coal zone on the north, is Scandinavia, on the south, the Mediterranean countries, both regions of minor importance and relying chiefly upon water-power. In only one country of Europe —Roumania—is petroleum the most important energy resource. In Europe as in the world as a whole it is largely coal which motivates industry.

The map and the data upon which it is constructed furnish a basis for further interesting comparisons which may serve to correct false notions. Thus the coal and lignite output of the Netherlands of which the world hears little are shown to approximate in present importance

Reduced to a per capita basis the power map presents a marked contrast to Fig. 2. Viewed thus (in Fig. 3) Norway ranks second only to the United Kingdom; Belgium is slightly larger than Germany and Switzerland exceeds France. In general the mountainous countries, rich in water-power resources but with sparse populations, show a large per capita output. Russia with its large population but retarded power development is reduced to insignificant proportions.

The power map is of course not an accurate index of industrialization since it represents *output*, not *consumption* of power.[3] England and Germany export much power as coal, Norway and Switzerland considerable quantities as electric current. On the other hand Italy imports more power as coal than she produces from her harnessed water-

[2] Data for 1926 were used where available except for Great Britain where the coal strike made that year abnormal.

[3] The per capita consumption of fuel for heat and power in England, which leads all European countries, is about 4.5 tons; in the United States it is approximately 8 tons.

falls. On the whole, however, the dominant position of coal in the power world and the high cost of its transport gives the countries producing it a tremendous advantage in international markets for manufactures.

It may be contended that since the original supply of coal is definitely limited while water-power is permanent that the coal countries have the advantage only temporarily. However, for the chief coal-producers the reserves are so large and their power production is so far in the lead that there can be little fear of their losing their place for many years to come. This is especially true in view of the marked improvement in efficiency of coal consumption and the superior adaptability of that fuel for industries requiring much heat, such as smelting.

On the other hand, it is interesting to note the rapid increase in relative importance of both water-power and petroleum in the power world during the past few years. The petroleum output in 1927 was nearly two and a half times that of 1913, while water-power development has increased by almost half since 1920. The United States, Canada and Europe have been very active in hydroelectric development, but European activity, at a high level during and just after the war, has slowed down. The cost of water-power installation is high and with the necessity for exploitation of less favorable sites it is bound to become higher. War impoverishment

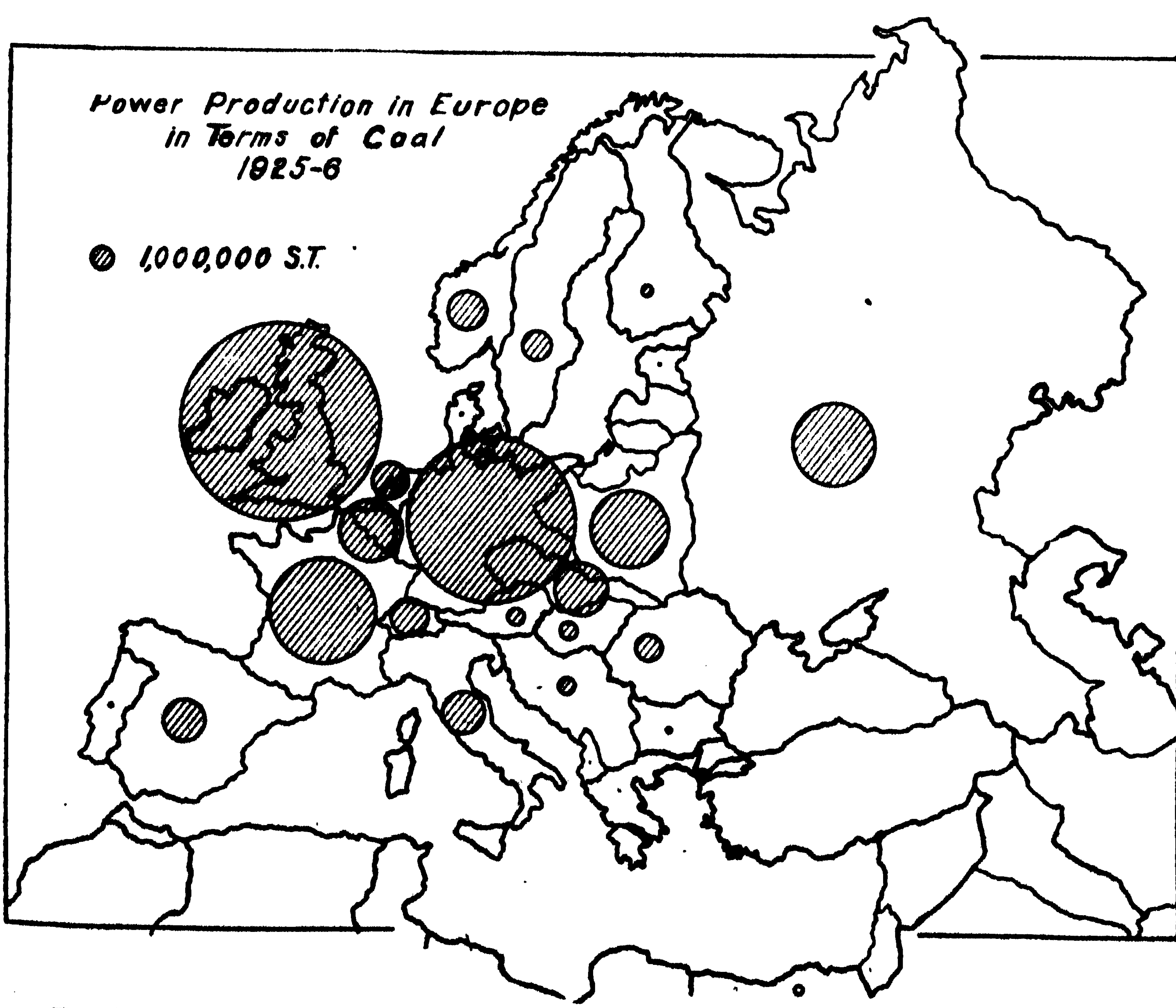


FIG. 3. NOTE THE IMPORTANCE OF THE COAL-PRODUCING COUNTRIES IN POWER PRODUCTION. THREE COUNTRIES ACCOUNTED FOR ABOUT 75 PER CENT. OF THE EUROPEAN OUTPUT.

and dearth of capital are conditions better suited to the use of coal. The "age of white coal" and the "age of oil" of which so much is heard are not with us yet. All of the water-power of the world developed to date (about 3 per cent. of the total potential) is replaceable by only about 116 million short tons of coal, a little more than the yearly output of the state of West Virginia, while all the world's petroleum production is equivalent to the combined coal output of but two states—West Virginia and Pennsylvania.

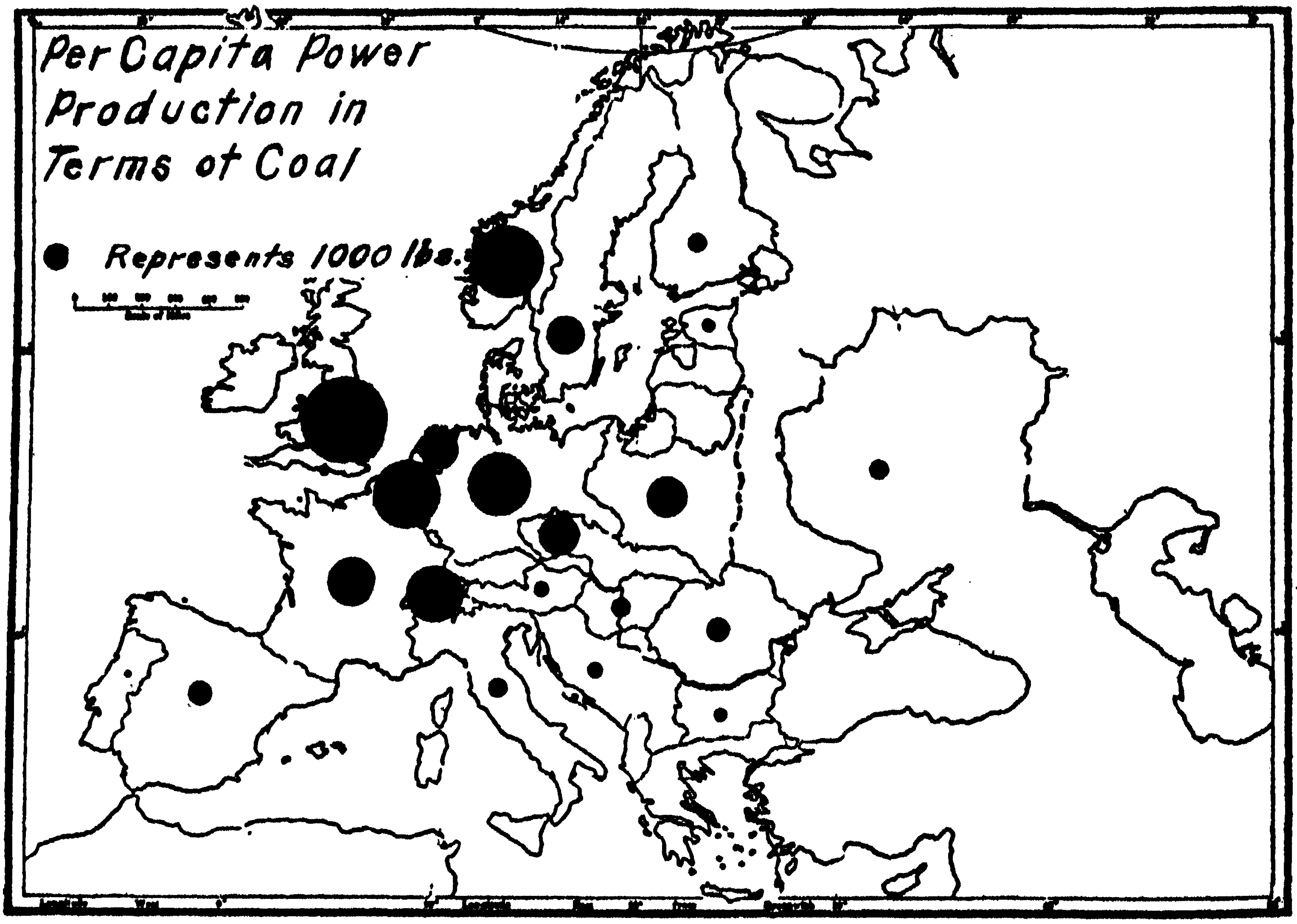


FIG. 4. THE MOUNTAINOUS COUNTRIES SUITED FOR LARGE WATER-POWER PRODUCTION BUT UNSUITED FOR DENSE POPULATION SHOW A LARGE PER CAPITA POWER OUTPUT.

FAMILY AND CONJUGAL AFFECTION AS A FACTOR IN HUMAN EVOLUTION

By RALPH E. DANFORTH
CHESTERFIELD, MASS.

It is surprising to see how many intelligent people have the impression that the eugenics program slights the value of *love* in family ties. Doubtless there are eugenists who have not thought much about the rôle of affection, but I imagine that the cause of this popular misconception may be due to the fact that the average writer or speaker on eugenics takes the importance of love so much for granted that he either omits to mention it or passes it over with a few words, such as: "Of course, conjugal love is only strengthened and made more permanent by judicious selection of mates worthy of parenthood and general high esteem."

On the other hand, the public is proverbially suspicious of new truths, and smells taints and dangers in discoveries of the soundest worth. To this all history attests.

Eugenics comes in for its full share of the public suspicion, and perhaps the commonest complaint is that it would do away with all love.

An objection often raised is that we should leave all matters concerning the heredity of coming generations to God, that he is taking care of that, and we need not think about it. This second objection I hope also to treat, though briefly, before closing this paper.

Zoologists have long studied the many interesting cases of parental care and affection shown by many species of animals, high or low. Many birds mate for life; many keep within sight or hearing of the mate year in and year out. Our own class, the mammals, universally care for the young for a while, although many species have but fleeting affection for their mates. We need not add that some human mammals have been known to suffer this same lack. Even among the lower or cold-blooded vertebrates remarkable cases of parental care for the young are not infrequent among the amphibians and fishes. Insects and other invertebrates exhibit some striking examples of parental solicitude.

All such cases—and particularly in the higher vertebrates and man, care, affection and love, where such exist—are admitted by scientists to have a very important bearing on the evolution of the species, giving it certain advantages not possessed by species or individuals not exhibiting such care, affection or love.

We may safely conclude that the higher love for mates, for children and for family which we find quite commonly in the human species has been an important factor in our attaining our present superiority. Instinctively also we estimate the relative superiority of people not only by their intelligence but also by their superior endowments in affection and in kindness. Unselfish love is coming more and more, as history advances, to be esteemed a supreme gift.

Family and conjugal affection, having done much to bring us to our present stage in our racial and our family evolution, will be needed even more in future generations to bring us toward that perfection for which we earnestly aspire.

In dealing with a subject like evolution we can not too often remind ourselves that however interesting our evolution in the past may have been, it is our evolution in the present and future which most vitally concerns us. Our

interest in this should be a hundredfold greater than in that which has gone before and is now only a record of what is done and finished for all time. History is interesting and is also a useful source of many suggestions for practical use in the present and future, but what we are now achieving and what we are preparing to achieve and to become are worthy of our intensest application.

No thoughtful person considers the human race at all complete or perfect in its present state. Our conception of an all-wise God would be compromised if we thought he had finished his creation of man, knowing, as we do, how imperfect mentally even the smartest and best of people are. Physically and morally also the race needs improvement, while spiritually the room for growth is infinite.

God's creation of man is still in process.

Many are the factors being used in the process of building up man into the being he should be. Intelligence, common sense, discretion, language, ambition, hope, purpose are a few of these factors. Family and conjugal affection is one of the essential factors without which human evolution can not continue in an upward direction.

Real, true, abiding love for one's mate is absolutely essential for the happiness of the family and the welfare of society. This quality of deep, enduring love should be assiduously sought after in selecting a mate. Without this love there should be no marriage. An inexpressible, deep and beautiful love should grace every matrimonial union. To produce a race devoid of these priceless traits would be a eugenic calamity, an evolution backward. These facts should be more clearly emphasized by eugenists than they have been hitherto, if we would allay ignorant opposition on the part of the well-meaning public. True love, so far from being foreign to the program of eugenics, is one of the most vital factors in human evolution and will be increasingly so as the race rises to higher and yet higher levels.

True love and the eugenic selection of a mate, so far from being antagonists, are the strongest of allies. Nothing could be more absurd than the thought that the use of a little discretion and common sense in the selection of one to whom one will be inseparably bound for life is a killer of love.

For the love of a thoughtful and capable person to endure and to deepen with time there must be worthy qualities in the one loved, qualities which appeal not only to his love but also to his respect and admiration. He or she will, sooner or later, find love giving way to chagrin when there comes the realization of a general lack of worthy qualities on the part of the mate. The best way to forestall this falling off of love is to make sure that the mate is in every way worthy of the deep love bestowed. The best guarantee that love will grow deeper with time, throughout one's wedded life, is a judicious exercise of care as to whom one should marry. To say that this is a joy killer, a stifler of love, is farthest from the fact.

Many who are inclined to look askance at scientific innovations readily pin their faith on time-honored popular mottoes. One of the truest popular mottoes is, "Marry in haste to repent at leisure." In this the "haste" refers not so much to speed as to lack of thought and discretion. One can hardly marry too quickly when sure all is right. For the unscientific type of mind this motto furnishes an excellent working basis for eugenics. This repenting at leisure is most hostile to true love. Those who have thought eugenics a love-killer had better open their eyes and their hearts to eugenics as one of

love's most fundamental allies. Eugenics is the making sure that one is worthy of being loved. Eugenics ascertains, as far as possible, beforehand that there are qualities making for the permanence and increase of love. Eugenics discourages loveless matches, which are made far too often by the unscientific for material or sensuous or selfish motives, and would encourage and insist that there should be true love and real merit deeply rooted in both of the contracting parties.

Eugenics is, in part, a sincere effort to ascertain what good qualities are in an individual. In studying the individual person its methods are twofold. It finds out the real worth of the person by studying the person. To this study of the person himself it adds the study of the performance record of his parents and grandparents, and, when possible, of his great-grandparents, not so much to see if there was any evil in them as to find out how much good was in them as registered by their achievements. We expect to find some worthless or mediocre ancestors in every such search, for there are, as yet, no families so well-weeded as to be without them. But we have a right to expect that a truly worthy person should have a goodly proportion of ancestors who have achieved useful deeds, lived nobly and served their community unselfishly. Eugenics wishes to prove that the individual person possesses physical, intellectual and moral traits which are both excellent and capable of being transmitted by heredity to the generations yet to come. The finding of some flaw or imperfection in the ancestry need not kill all love, as some would fear, but the superabundance of foolishness or selfishness of the ancestry, or too large a proportion of such undesirable ancestors might rightly prejudice one against his budding affection. On the other hand, the finding of a goodly proportion of excellent, intelligent, healthy ancestors of the loved one would rightly enhance the love, confirming the personal judgment of the merits of the loved one. One could then love more ardently than ever and feel pretty confident that as time passes one will never regret the choice.

Eugenics then may fittingly be called the handmaid of true love. The higher we rise, as a race or as a family, the more intelligence is required in our everyday life, in our business, in our eating and in our exercise. Increasingly more intelligence will also be required in our choice of lovers. This is only in keeping with the required increase of intelligence in every other department of our life.

Love and affection are the most beautiful elements in all the universal range of beauty. Sordid indeed and low would be the life without love. A most disgeneric individual would he be who had no appreciation for love of the truest and deepest sort. Such people would be among the first to discard in our eugenic selections. Among the qualities one would seek are health, beauty, intelligence, power to succeed, honesty, cheerfulness, tact, faithfulness, love, in rising scale of importance. These qualities should be well represented in the individual loved and also found in a good *majority* of his or her ancestors.

As the future generations pass, under the eugenic plan, one could insist upon increasing excellence of ancestry, because the eugenic selection would gradually and steadily reduce the inferior ancestral minority and increase the superior ancestral majority. The quality of each succeeding generation born into the world would improve, although for some time to come some black sheep would occasionally recur. Many semi-black sheep or only moderately desirable persons would recur, but in time

even these would tend to give place to the truly superior individuals. These should become ever healthier, brighter and more loving as the centuries roll on.

I hope that the reader can see clearly that the exercise of wisdom and vision in selecting lover and mate is an aid, not a hindrance, to true love. The other objection often raised, that we should leave all such considerations to God to take care of for us, is not in line with our intelligent Christian living in any of the other departments of our life. We do not leave entirely to God the provision of our food and all its preparation for the table; we do not expect Him to fit and sew our clothes and then dress us each morning; we do not ask Him to run our business without any thought or cooperation on our part, or our professions or our homes. We take it for granted that He gave us brains and hands to use rather than for purely ornamental purposes. Our brains certainly are not ornamental. We do not leave all our courting and love-making to God. If we lay all the results and consequences of our courting and love-making to God, in order to be consistent we should also let Him attend to the courting for us, with no cooperation whatever on our part. Now the true Christian believes that God is truly interested in the success of his life, his business and his family and that God expects him to do his part to make all these a success, to use hand and head and heart to bring about this success. The use of at least the same amount of intelligence and forethought in courting as in the less important branches of activity is demanded by common sense and by love alike. We have no right to blame God for the fools born into the world if we make fools of ourselves at the very fountain of life. The Creator is wonderfully patient, but perhaps there is a limit to His patience even in His great plan for the uplift of the human race.

In the title of this article I purposely link together *family and conjugal affection* as one entity. One capable of the loftiest love of mate will also have deep love of family. Far too many people are deficient in the true, abiding love for mate and for family. Family is more than father, mother and children; it is *clan.* This includes a group of related families, with an extensive ancestry reaching back into the past, and an extensive progeny reaching forward into generations to come. There should be more love and loyalty to mate and to family. Family is like a great river made up of numerous streams of mingling waters. When one selects a mate unwisely one not only dishonors one's own personal family, but one dilutes the greater family stream or may even thus pollute it. One thus dishonors true love and dishonors the family.

One belonging to an intrinsically noble family, whether it be ranked with the "nobility" or not, honors and makes more noble that family by every wise choice of superior blood and brain and heart and soul.

Family and conjugal affection is one of the greatest factors in the future evolution of man.

In this wonderful age of science in which it is our privilege to live, each day brings forth new wonders, life becomes richer by each discovery and invention, methods change and our outlook upon life and the world changes with them. These all go to make up part of what we call our "civilization," but they do not change our real selves. It is conceivable that civilization might advance while we were retrogressing. But all our innovations and new knowledge may be used to beautify the world we live in and make it more healthful and pure. May we so live and so love that the species and the environment may both improve together. So far at least as our own family is concerned let us love and toil for its upbuilding.

A MILLION YEARS OF EVOLUTION IN TOOLS

By MILDRED FAIRCHILD and Dr. HORNELL HART
BRYN MAWR COLLEGE

IN the attempt to measure past changes in human culture the longest and most complete series of data available consists in the tools with which man has cut and shaped his materials. This series extends in unbroken line over immense stretches of time. Flints chipped by human hands into crude cutting blades have recently been shown to belong to geological strata laid down in England about 1,300,000 B. C.[1] Between these oldest of man-made blades and the most modern cutting devices of Pittsburgh machine shops there is available a practically unbroken series of cutting tools, dated with sufficient accuracy to permit an objective analysis of the relative rates of progress in their efficiency at various points in this tremendous sweep of time.

That progress in cutting tools has been going forward at an accelerating rate is evident from a series of blades representing the various cultural epochs. Fig. 1 offers sketches of artifacts for such a series. Beginning at the lower left-hand corner, and reading up, we have in the first column four cutting blades representing the development of man's facilities for cutting and shaping materials during the nine hundred thousand years roughly from 1,300,000 to 400,000 B. C. The lowest of the four is a sub-Red Crag rostrocarinate flint from Bramford, England. Such flints belong to the Eolithic, or "Dawn-Stone" Age. Also included among Eolithic flints (though not represented in this chart) are the types found at Foxhall, England, dating perhaps one hundred thousand years later than the sub-Red Crag. Still later, though belonging also to the preglacial Eolithic level, came the flints associated with the skull of the "Dawn Man" found at Piltdown, England.

The second drawing from the bottom in the left-hand column of Fig. 1 represents a specimen of the giant flints found at Cromer, England, in strata contemporaneous with the first glaciation, between 900,000 and 800,000 B. C. At about 700,000 B. C., in what is now France, occurred a culture level not represented in the chart, known as pre-Chellean. The third flint in the chart is a Chellean tool.

If the Chellean, pre-Chellean, Cromerian, Piltdown, Foxhallian and sub-Red Crag flints were shuffled and presented to the reader, it would require the closest study for him to determine which of them came first, so slow was progress in cutting tools during the seven hundred thousand years which they represent. The Acheulean and Mousterian, however, begin to take shape in a way which puts them at once, even for the layman, above the cruder flints which preceded them.

Upper Paleolithic, comprising Aurignacian, Solutrean and Magdalenian cultures, was the time of the Cro-Magnon race. Solutrean tools are represented in the chart by the beautiful "laurel leaf" type of blade. The Magdalenian is represented by a flint knife which, instead of being elaborately chipped out like its predecessors, was struck off at one blow with little or no

[1] Henry Fairfield Osborn, "Man Rises to Parnassus," pp. 23–5, 1928.

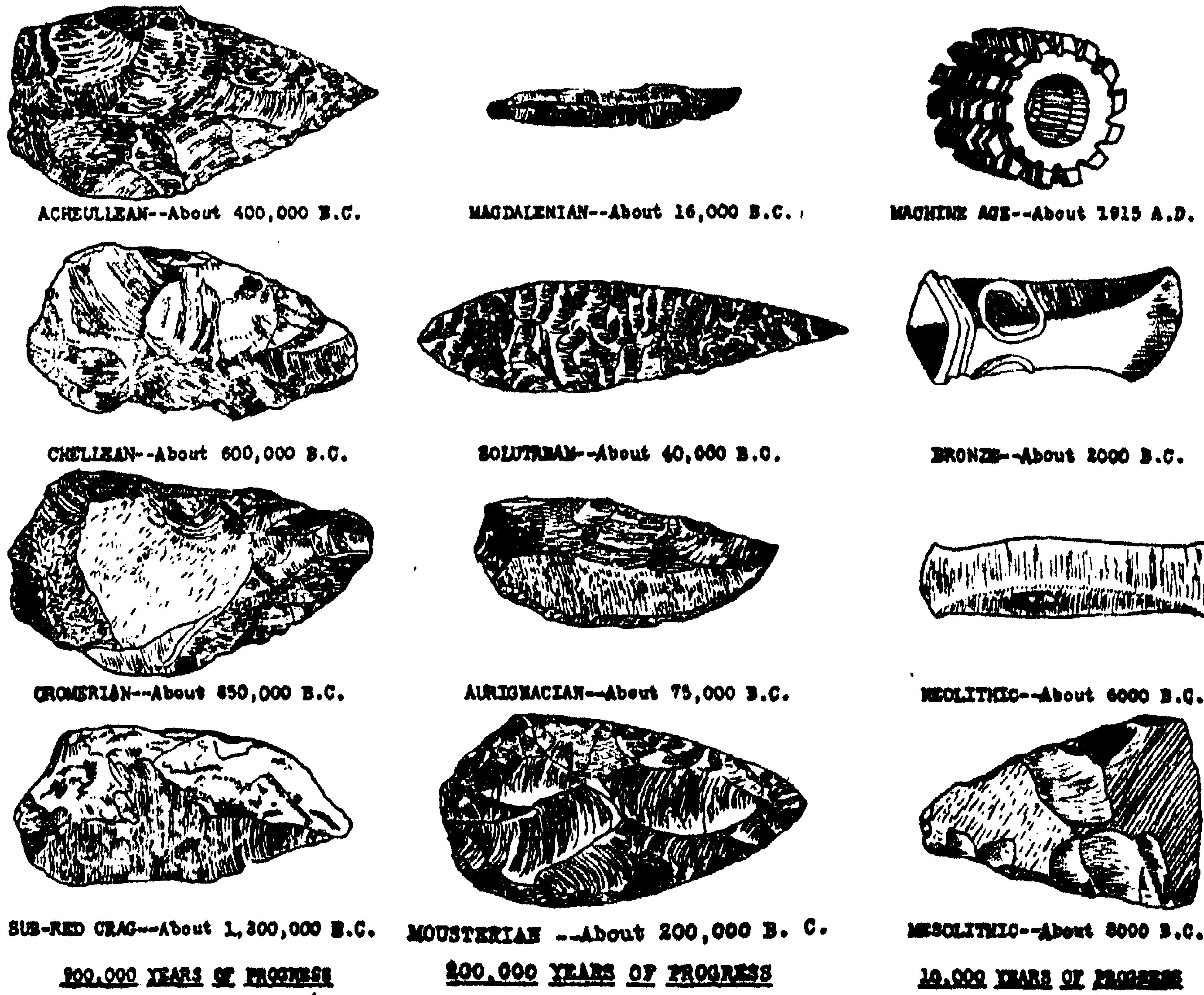


FIG. 1. ONE AND ONE THIRD MILLION YEARS OF EVOLUTION IN CUTTING BLADES.

retouching, in a highly skilful and time-saving way.

The Mesolithic, or Middle Stone Age, includes a variety of cultures. Its representative in the chart is a stone axe-head from Campigny, France. The distinctive feature of this cutting tool is that the edge is partly ground down to sharpness instead of being merely chipped out. The Neolithic specimen carries this development to its logical conclusion and has a completely ground and polished stone axe-head. Leaping over the Copper Age, and many intervening steps in that and the Bronze Age, the next specimen is a socketed bronze celt. Leaping again over the Iron Age, the sketch at the top of the right-hand column in the chart represents a complicated blade used in modern machine-shops for cutting worm gears out of steel.

Without in any sense casting reflections on the prehistoric craftsmen who developed the Acheulean and the Mousterian tools, it seems fairly obvious that the absolute progress in the efficiency of cutting blades during the past ten thousand years in Europe has certainly not been less than the progress during the first million years in the series. If this is true it means that the rate of progress in the last column is at least one hundred times as great as in the first column. Such a conclusion is of fundamental importance—so much so, indeed, that it drives the investigator to ask whether this tendency can not be more accurately measured.

If a quantitative statement of progress in cutting tools is to be made, the first problem is to arrive at the nearest feasible approximation to an objective scale of points by which to rate such tools. Analysis indicates that at least five variables enter into the efficiency of man's cutting tools: (1) Keenness and durability of the cutting edge; (2) differentiation and specialization; (3) effectiveness of mechanisms employed to apply the blade to the materials to be cut; (4) utilization of auxiliary power, and (5) mastery displayed in the technique of manufacture.

Keenness and durability of cutting edge may be represented on a performance scale of which three levels may be defined and dated with fair accuracy. The lowest test is flaying the skin from a dead animal, for which two points out of a possible 20 may be allowed. For blades capable of chopping down trees, five points may be allowed. The highest degree of keenness-durability thus far attained is fairly well represented by the capacity of the cutting blades in a modern machine tool to cut cold steel, or, taking the extreme of delicacy instead of the extreme of strength, the capacity of a modern microtome to slice off cross-sections one twenty-five thousandth of an inch thick for microscopic slides. These degrees of attainment may conservatively be rated at twenty points.

The application of this scale to the series of blades from earliest prehistoric times down to the present produces the ratings in column 3 of Table 1. Before Acheulean times flint blades had the crudest sort of rough cutting edges, very easily dulled by use even against hard wood. Acheulean, Mousterian, Aurignacian and Solutrean blades progressively developed more and more accurate "retouching," whereby the cutting edge was made keener and keener by taking off small chips from the margin. The Magdalenian blade produced a fragile but sharp edge at one stroke. The Mesolithic *tranchet,* or flint axe, with its edge sharpened by grinding, gave craftsmen for the first time a tool capable of felling a tree and of hewing out a log canoe.[2] Further developments of this grinding process in Neolithic times made possible the use of harder stones and the production of keener and more permanent cutting edges. Copper working introduced for the first time metal blades, and the development of bronze made available a more durable and keener edge. Iron and steel brought cutting power which was for centuries regarded as magical. Modern methods of alloying, hardening and sharpening have produced the supremely strong and delicate edged blades of to-day.

The second criterion—differentiation and specialization of tools—is an indirect index: the greater the variety of tools, and the greater the extent to which they are adapted to specific cutting processes, the greater is the efficiency of each tool apt to be. The best comparative study of specialization in Paleolithic tools is given by Osborn.[3] His tabulation shows that pre-Chellean culture had such tools as knives, planers, scrapers, borers and hammer stones. The Upper Paleolithic made huge strides forward. It added chisels, etchers and graving tools of flint; it developed a wide variety of bone implements, such as the spatula, shuttle, pin, needle, wedge and awl. It added such weapons as the barbed dart and harpoon. The Magdalenian period had nearly seven times as great a variety of flint and bone tools as the pre-Chellean. The Azilian (one of the Mesolithic cultures) dropped to a little more than half the variety of the Magdalenian. The Campignion, however (another Mesolithic culture) added to the toolbox of the Paleolithic artificer the pick and the stone axe with a ground edge.

[2] "Man Rises to Parnassus," p. 113.

[3] "Men of the Old Stone Age," pp. 270–1, 1916.

Mesolithic at its best, therefore, represents further progress.[4]

The metal ages opened up new possibilities in tools, greatly accelerating the tendency toward specialization. The Egyptians passed into the Copper Age about 3100 B. C. Copper saws made it possible to cut out the great blocks of stone for the pyramids. The Bronze Age developed fully in Egypt about 2400 B. C. As late as 2100 B. C. stone was still employed for the cheapest of knives used by the fellahin for chopping up meat, and for the arrow-heads which once shot off would never be recovered. Razors and fine daggers, however, were now of finely-tempered bronze, while ordinary knives and weapons were of copper.[5]

As the metal ages proceeded a greater and greater variety of tools became possible. Some idea of the rapid introduction of new forms may be gained from the fact that during excavations on the site of the prehistoric village of Glastonbury, England, which flourished in the Iron Age, about 800 B. C., there were found daggers, spear-heads, swords, knives, bill-hooks, sickles, saws, gouges, adzes, files, bolts, nails, rivets, keys and bits.[6]

Rich as was the variety of tools in classical times, recent developments outshadow the past in this respect as much as in keenness. Consider the catalogue of the modern wholesale hardware dealer in comparison with any inventory of ancient implements. Think of the bewildering variety of tools in the cabinet of a modern dentist or surgeon; examine the kit of the cabinetmaker; enumerate the implements of the engineer or miner, or even the butcher of to-day, and the past specializations of tools fade into relative insignificance. We have special cutting devices to trim off the edges of great piles of book pages, to slice off paper-thin sheets of ham, to sheer a steel rail, to bore a hole under the Hudson, to scoop out a Panama Canal, to cut at one time the pieces of cloth for a score or more of suits, or to bore a well in an oil field. Even fire and chemicals play their part as controlled cutting devices; the oxyacetylene torch eats swiftly through hardened steel; dynamite tears out stumps and splits off coal or granite.

The third variable to consider in rating the efficiency of prehistoric, ancient and modern cutting tools is the effectiveness of the devices employed for giving the cutting blade the desired motion through the material to be cut or shaped. The earliest flint blades were, apparently, grasped merely with the bare hands of the craftsman. The first step toward a mechanical device for directing the blade was hafting—attaching the flint by means of withes, tendons or rosin to the ends of sticks used as handles. Because of the perishable nature of such attachments and because the earliest hafted blades may not have been shaped perceptibly to accommodate their handles, the exact period at which hafting commenced is doubtful. Generally it is thought to have begun late in lower Paleolithic; there is no question that Aurignacian, Solutrean and Magdalenian flints had handles.[7] A further refinement of hafting occurred in Magdalenian and particularly in Mesolithic times, when the composite tool was developed. This consisted of small flint teeth (microliths) which were set into bone or wooden handles to form harpoon heads, saws, and, in Neolithic times, sickles.

More impressive as mechanical devices were the early drills. Rotary motion in blades for boring was first secured by

[4] R. A. S. Macalister, "A Text-book of European Archaeology," p. 552, 1921.

[5] "Cambridge Ancient History," Vol. I, p. 319.

[6] Quennell, "Everyday Life in the New Stone, Bronze and Early Iron Ages," p. 185, 1923.

[7] Kroeber, "Anthropology," p. 178, 1923.

twirling the drill handle between the palms. Then came the idea of twisting a string around the handle and obtaining the whirling motion by pulling the string. By late upper Paleolithic times the bow had been invented and was being used, by giving its string a turn around the shaft of a drill, to produce rotation. The crank drill, with stone fly-weights to keep it whirling, was invented in Egypt between 3400 and 3000 B. C.[8] The drill brace was used by the Assyrians in the seventh century B. C.[9] Another device for rotating cutting edges was the circular millstone, invented in the Iron Age.[10]

Another class of mechanical device whirled the material to be cut or shaped instead of twirling the cutting blade. The earliest machine of this sort was the lathe. Its original form was a development of the bow drill, which probably evolved in the Bronze or early Iron Age.[11] A kindred device was the potter's wheel. This appeared in Egypt before 3000 B. C. and was evidently used much earlier in Elam.[12]

Handles and whirling devices practically exhaust the prehistoric and ancient contributions to the solution of the problem of imparting mechanically the proper motion to the cutting blade and material. Very little progress in this field occurred in medieval times; the wheel-driven lathe giving a constant rotary motion to the wood was a novelty as late as the 14th and 15th centuries: the predominant type was still the strap lathe, in which the piece to be cut was whirled alternately forward and then back.

The real development in mechanical devices for controlling cutting blades has occurred since the beginning of the industrial revolution. In woodworking, for the quantity production of such objects as gun stocks, the modern mill has copying lathes which automatically turn out any shape desired. The same thing is done in metal working. Into one end of an automatic machine are fed steel rods or sheets; out of the other end, without guidance by human hands, come finished screws, bolts, machine parts, or what not. The modern automatic machine thus handles mechanically the entire process of imparting the correct cutting motion to the blade—a process which until two or three centuries ago was almost entirely carried out by direct manual dexterity.

The fourth variable to be rated in sketching the curve of evolution of cutting tool efficiency is the application of power to the tool. During the whole lapse of the stone ages the power applied to tool-driving was entirely human. Rudimentary progress was made in the more effective utilization of this power: the handles applied to stone axes, and the bows employed to drive drills were not merely for the purpose of imparting the desired motion but also for the sake of imparting more power. In Aurignacian times[13] the invention of the bow put at the disposal of the hunter new power for the propulsion of flint-tipped arrows. The spear-thrower, which appeared in Magdalenian times, augmented the force of the human arm.

Neolithic domestication of animals brought new power reinforcement. It was not, however, until the Bronze Age, sometime before 2000 B. C., that the ancient Egyptian first took the step of putting onto his hoe the attachments needed to turn it into a horse-drawn plow.[14]

[8] Breasted, SCIENTIFIC MONTHLY, 9, p. 571, 1919.

[9] *Britannica*, 9, p. 69, 1910–11.

[10] Quennell, *op. cit.*, p. 180.

[11] Quennell, *op. cit.*, pp. 130, 191 and 202.

[12] "Cambridge Ancient History," 1, p. 320.

[13] Sollas, "Ancient Hunters," pp. 356, 359, 1924.

[14] Breasted, SCIENTIFIC MONTHLY, 9, pp. 424–5, 1919.

It was the ancient Egyptians also, according to Quennell,[15] who first harnessed water-power by mounting in midstream a boat with millstones geared to paddle wheels. The ancient Romans worked their millstones by horse-power, slave power, and probably water-power. The early Anglo-Saxons drove their mills by donkey power before A. D. 500. In the eighth century they had mills driven probably by water-power. Windmills began to be used in England as early as A. D. 833. It is supposed that they were introduced from the east by crusaders. The Middle Ages show progressive minor improvements in wind and water mills. Wind-power was harnessed to saws in England about the beginning of the thirteenth century, and it was soon followed by the use of water-power, but opposition on the part of hand sawyers prevented any widespread development of power sawmills until their adoption in America in 1634. A trip-hammer run by water-power was introduced in England in the seventeenth century.

The invention of the steam-engine, and the discovery of coal as a fuel, marked, of course, a new epoch in the application of power to tools. While steam has multiplied overwhelmingly the amount of power available, it has not monopolized the field. The development of the water turbine has given water-power a resurrection of usefulness. The invention of electric generators and the introduction of compressed air devices made possible the application of power to small and isolated tools inaccessible to direct steam drive. Tools used in mining and quarrying, and tools employed in family kitchens, illustrate the new fields opened up by these auxiliary forms of power. The gasoline engine provides another easily moved power unit, which is likely to displace the horse in driving agricultural tools. The old standard for plowing used to be one acre per man per day; the tractor-hauled gang plow does twenty-two acres per man per day. Both in the amount of power available, and in the versatility of its forms, the progress in the past three centuries towers vastly beyond all the developments of the preceding million years.

The accelerating increase in the amount of power available may be illustrated by the fact that at the close of the Civil War the manufactures of the United States employed less than 1.3 horse-power per wage earner; in 1922 3.8 horse-power per wage earner was used. This means that in this country since 1869 more than twice as much power per worker has been added as had been acquired in all the hundreds of thousands of years preceding. During this period, moreover, the increase in horse-power has been accelerating.[16]

A spectacular phase of the accelerating mastery of power is stated thus by Frank Bohn:

> Thirty years ago the best steam turbine on the market used five or six pounds of coal to produce a kilowatt hour of electricity. Two years ago the new unit in Brooklyn used exactly 1.4 pounds. The most efficient new plant now requires only .85 pound.[17]

The remaining criterion of progress in tools relates, not to the effectiveness of the instrument as a means of cutting and shaping materials, but rather to the mastery displayed by the craftsman in the production of the tool itself. That mastery may be judged by at least two qualities remaining in the tool: the standardization of design, and the beauty of form, material and ornamentation.

Before the Acheulean period there is little in the cutting tools of prehistoric

[15] "A History of Everyday Things in England," Vol. I, p. 95.

[16] U. S. Census, Vol. VIII, pp. 14, 15, 22, 1920; *Industrial Management*, Vol. 72, pp. 364–72, Dec., 1926.

[17] New York *Times Magazine*, p. 1, Oct. 2, 1927.

man to suggest handicraft mastery, or indeed, anything which might be called a developed technique of manufacture. Osborn says of the Chellean period that "at this dawning stage of human invention the flint workers were not deliberately designing the form of their implements, but were dealing rather with the chance shapes of shattered blocks of flint, seeking with a few well-directed blows to produce a sharp point or a good cutting edge."[18]

With the Acheulean period, however, specific forms and characteristic designs become apparent. And in the Mousterian, "points" struck off from the flint core with a single blow after a careful flaking and retouching had prepared the surface and edge, show definite technique.

From that time on, with one or two possible exceptions in so-called degenerative periods, a progressively increasing mastery of technique appears. Obviously the artificer acquired more and more skill to take off his flakes delicately at the points which he selected, and to control the shape of the tool he produced. The forms became less haphazard and more standardized; the shapes approached more and more to beauty. By about 40,000 B. C. flint instruments had developed in the hands of Cro-Magnon man to the "Solutrean" level. Instead of being knocked off by sharp blows, the flint was chipped off by pressure in fine, thin flakes from the entire surface of the implement, to which in its perfected form the craftsman could give a keen edge and perfect symmetry. Definite progress is in evidence, but progress attained only during the slow passage of tens of thousands of years.

With the increasing use of bone and ivory as materials the etching of designs, already presumably well started on wooden implements, came into prominence on cutting blades. As tools of bone became more beautiful, flint chip-

[18] "Men of the Old Stone Age," pp. 129 and 152.

TABLE 1

RATINGS OF THE EFFICIENCY OF CUTTING TOOLS AT VARIOUS CULTURE EPOCHS, FROM EOLITHIC TIMES TO THE MACHINE AGE

Period	Date*	Keenness	Specialization	Mechanisms	Power	Technique in manufacture	Total rating
1	2	3	4	5	6	7	8
Machine Age	A.D. 1915	20	20	20	20	20	100
Iron	500 B. C.	16	15	7	8	14	60
Bronze	2000 B. C.	12	13	6	5	13	49
Copper	4000 B. C.	9	12	4	2	12	39
Neolithic	6000 B. C.	7	10	4	2	11	34
Mesolithic	8000 B. C.	5	8	4	2	9	28
Magdalenian	16000 B. C.	4	7	2	2	8	23
Solutrean	40000 B. C.	4	6	2	2	7	21
Aurignacian	75000 B. C.	3	6	2	2	5	18
Mousterian	200000 B. C.	3	2	2	1	4	12
Acheulean	400000 B. C.	3	2	1	0	3	9
Chellean	600000 B. C.	2	2	1	0	1	6
Cromerian	850000 B. C.	2	1	1	0	1	5
Foxhallian	1150000 B. C.	2	1	0	0	1	4
Sub-Red Crag	1300000 B. C.	2	1	0	0	1	4

* These dates all refer to culture stations in England, France and Denmark, as estimated in Osborn's "Man Rises to Parnassus."

ping temporarily declined in technical mastery and beauty. In the Magdalenian period consequently many archeologists label the flint manufacture as degenerate. In this connection it might be well to remember the amazing beauty of the cave painting and engraving belonging to the period. The Magdalenians shared perhaps in the modern tendency to divorce art and technology.

The Neolithic period brought a renewed interest, not only in the new forms produced by the developed technique of grinding and polishing, but in the perfecting of chipped blades. The finest flints of any period belong to the Neolithic and early Copper ages. The technique of flint-working was at its height after metal began to displace flint.

Metal work probably found its earliest developments in jewelry, and it retained its decorative features as it was applied to tools and weapons. Ancient swords, daggers and knives vie with bowls, vases, breast plates and the like as objects of art. The skill and the joy of craftsmanship, moreover, found increasing outlet in the growing variety of forms and materials with which it could work.

The machine age has practically abandoned decoration of its working tools. There is an inherent beauty in the size, power and smooth efficiency of the modern machine tool. There is also increasing beauty of form and line and increasing attention to the attractiveness, as well as the efficiency of the materials used. On the whole, even so, beauty is not a primary characteristic of the modern machine tool.

Mastery of the technique of manufacture, nevertheless, has increased tremendously. With increased complication, large-scale production and division of labor, the joy of craftsmanship has been split up between the designing engineer, the draftsman and the machinist, if not also among a great many repetitive workmen who produce a standard product from a standard design. For the last, the joy of creative variation in their work has been removed. Nevertheless the finished product shows an almost incredible advance in design and perfection of manufacture. And to the designing engineers and to many skilled machinists the delight of fine craftsmanship has remained and, in some ways, has increased.

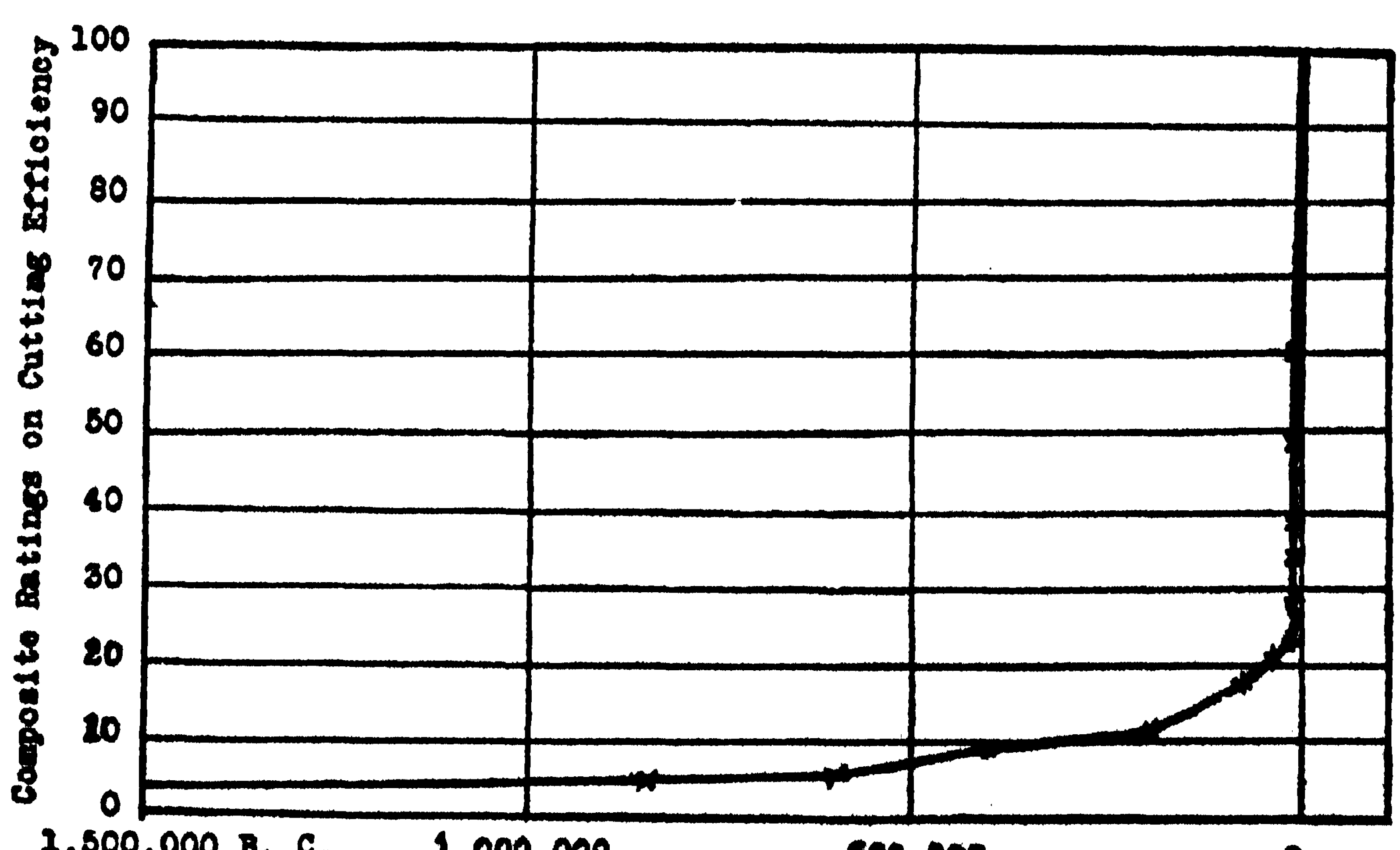


FIG. 2. ONE AND ONE THIRD MILLION YEARS OF PROGRESS IN CUTTING EFFICIENCY.

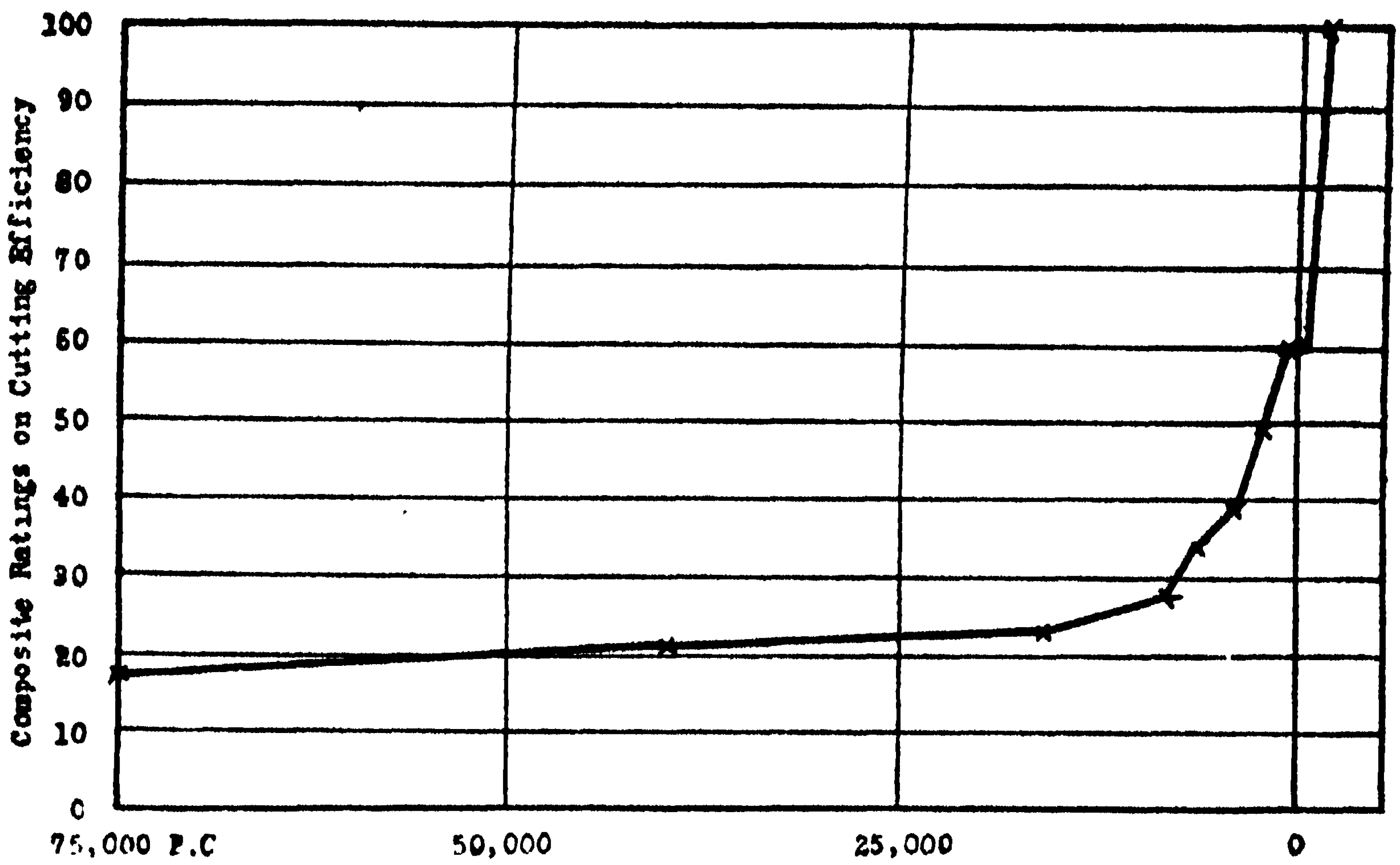


FIG. 3. THE LAST 75,000 YEARS OF PROGRESS IN CUTTING EFFICIENCY.

Reducing the above facts to a numerical basis, in ratings which severally run from 0 to 20, and which in total run theoretically from 0 to 100, the measures of progress presented in Table 1 are obtained. It is not, of course, asserted that these ratings have absolute objective validity; it *is* argued, however, that any intelligent student of the data will come to results so closely approximating these that the practical deductions will not be materially affected. It is suggested that the reader try the experiment of making his own independent ratings of the cutting tools of the different culture epochs, and that he chart the resulting curve for comparison with that given in Figs. 2 and 3.

The ratings presented in Table 1 and Figs. 2 and 3 reflect a rising curve of progress; for hundreds of thousands of years the gains are scarcely perceptible; then tens of thousands, and later thousands of years showed marked improvements. Now we no longer deal in centuries but find each decade or each year taking swift steps forward. The more and more rapid acquisition of new elements is not due to our lack of knowledge of early portions of the series; the increasing speed of invention is an unmistakable feature of the series itself. Except for temporary fluctuations, man's power to cut and shape materials has increased during the past million years at accelerating speed.

THE EVERGLADES

By Dr. JOHN K. SMALL

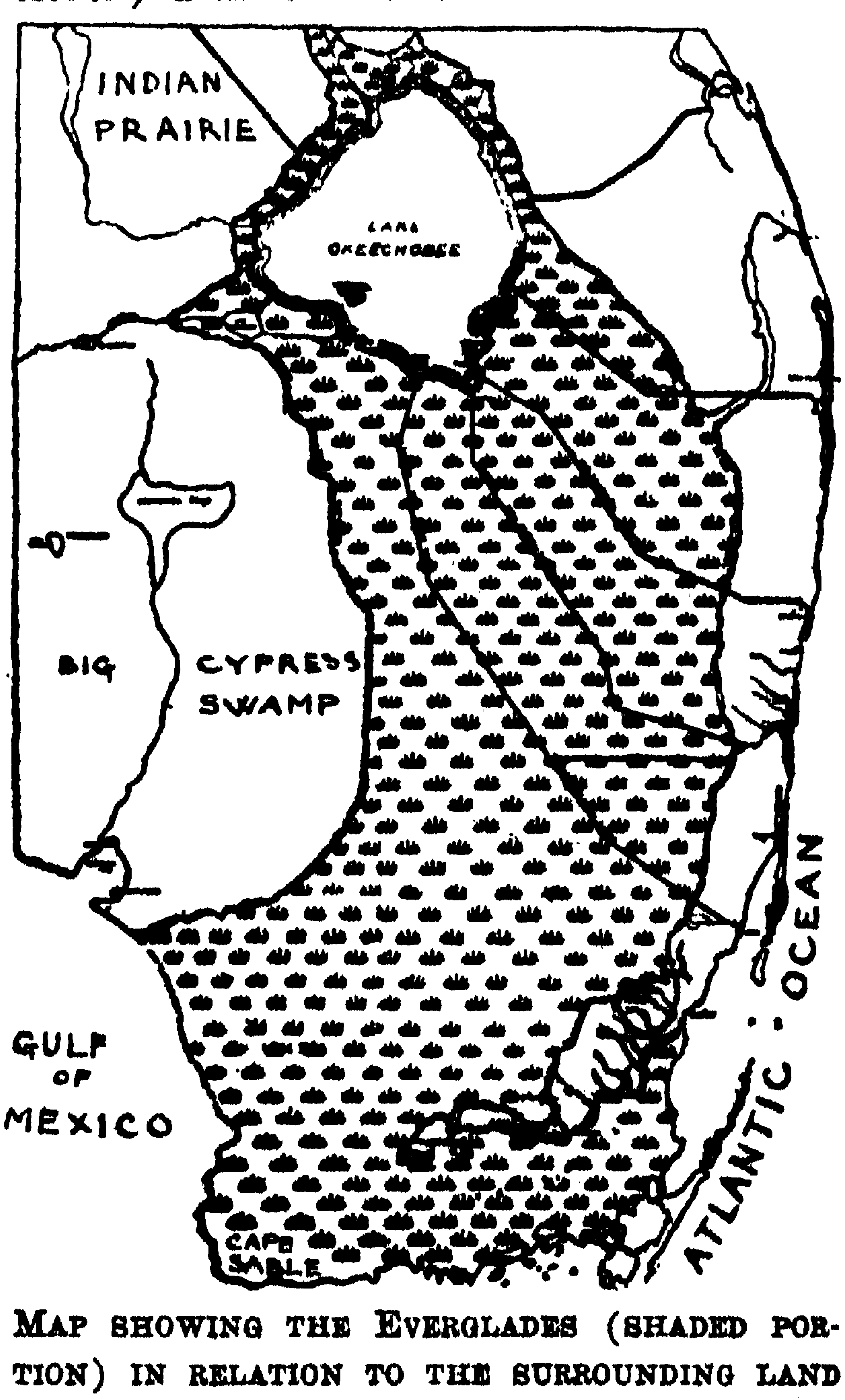
NEW YORK BOTANICAL GARDEN

THE Everglades—a unique natural monument and a very misconceived region—occupy about one half of the area of the Florida peninsula lying south of the head of Lake Okeechobee. To the mind of the uninitiated the Everglades are a vast, more or less impenetrable jungle, abounding in reptiles, birds and other wild animals. Nothing could be further from the real state of affairs. However, it is true that there are various intruded and sometimes included plant associations that collectively do harbor more kinds of aquatic, amphibious and terrestrial wild animals than any equal area in North America.

The Everglades lie in a shallow rock basin which falls off rather suddenly from the great Okeechobee prairie on the north and the pineland on the east, and very gradually from the Indian Prairie and the Big Cypress Swamp on the west. The area involved is over four thousand square miles. The acreage has been estimated as high as three hundred thousand.

As a result of the geologic structure of the Florida peninsula the Everglades are really a gigantic spring, perhaps the largest spring in the world. The tributary streams supply the area with a certain amount of water, but a vast amount must come from subterranean sources which follow with a slight southerly dip the nearly horizontal rock strata which underlie the surface of the peninsula. The outflow is certainly far in excess of the visible sources of its waters. The configuration of the surface, which is nearly flat except for the curvature of the earth, and the water supply are ideal for the growth of saw-grass (*Mariscus jamaicensis*). This is the characteristic plant of the Everglades, which are often referred to by the Indians as the "Saw-grass." Indeed, it is the largest saw-grass marsh in the world.

The Everglade prairie begins (at the north) a mile or two north of the head



MAP SHOWING THE EVERGLADES (SHADED PORTION) IN RELATION TO THE SURROUNDING LAND AND WATERS. THE STRICT FORMATION OF THE EVERGLADES IS AN UNINTERRUPTED PRAIRIE, WITH NOTHING IN VIEW EXCEPT SAW-GRASS AND SKY, AS SHOWN IN THE FOREGROUND OF FIGURE ONE. HOWEVER, SUCH A LARGE AREA NATURALLY HAS MANY SPECIALIZED FEATURES. SOME OF THESE ARE SHOWN IN THE ACCOMPANYING FIGURES. LAKE OKEECHOBEE IS ABOUT FORTY MILES IN DIAMETER.

THE EVERGLADES OR SAW-GRASS, WITH FRINGES OF PINELAND ASSOCIATION, OUTLIERS OF THE EVERGLADE KEYS IN THE DISTANCE. FARTHER NORTH IN THE EVERGLADES THE TOTAL LANDSCAPE IS THE SAW-GRASS PRAIRIE. CLOUDS OF SMOKE FROM A PRAIRIE FIRE MAY BE SEEN AGAINST THE SKY.

A WATER-HOLE IN THE EVERGLADES—AN IDEAL CAMPING PLACE FOR BOTH THE RED-MAN AND THE WHITE, BEFORE THE "GLADES" WERE TAMPERED WITH. SUCH DEEP HOLES FURNISHED COOL PURE WATER EVEN DURING THE DRY SEASON.

A SMALL SECTION OF ROYAL PALM HAMMOCK, THE LARGEST OF THE EVERGLADE HAMMOCK ISLANDS, WITH EVERGLADE PRAIRIE IN FOREGROUND. IT HARBORS ABOUT TWO HUNDRED KINDS OF WOODY AND HERBACEOUS PLANTS, MANY FERNS, AND A LARGE NUMBER OF ROYAL-PALMS.

of Lake Okeechobee. It fringes the lake, the fringing area becoming wider southward on both sides of the lake. The main basin has a gentle curve westward. The eastern side follows the rock rim of the eastern coastal region of Florida; its western side follows a nearly similar curve along the Indian Prairie and the Big Cypress Swamp. The Ten Thousand Islands form a kind of delta of the Everglades. There much of the surface-water finds its way to the Gulf of Mexico through a labyrinth of myriad channels. In addition to the delta-like outlet, the measureless water of the Everglades is constantly escaping in numerous surface streams flowing into the Atlantic Ocean, through the coastwise lagoons, Bay Biscayne and the Bay of Florida, through the Caloosahatchee flowing into the Gulf of Mexico, through subterranean streams, some of which show themselves as springs of fresh water off the shores of the ocean or in the coastal saline lagoons and bays, through the honeycombed limestone of sections of the coastwise ridge on the east, through general seepage and through evaporation from a surface of about three hundred thousand acres. These are the natural outlets for the Everglades' waters, not only unmeasurable but also unmanageable on occasion.

The balance of the surface waters and of the water-table, regulated through ages, was normally beneficial to the natural vegetation of the Everglades themselves and all the surrounding territory. With this water protection, climate was tempered and fires, at first a natural calamity as a result of lightning and later artificially started by the methods of primeval man, were relatively rare and evidently circumscribed. Furthermore, the many elevated parts of the Everglade prairie and the islands were tillable during the seasonal period of low water—the winter. Curiously enough the winter is the proper season for the growing of vegetable crops in that latitude. Likewise, under these natural conditions, the water-table was

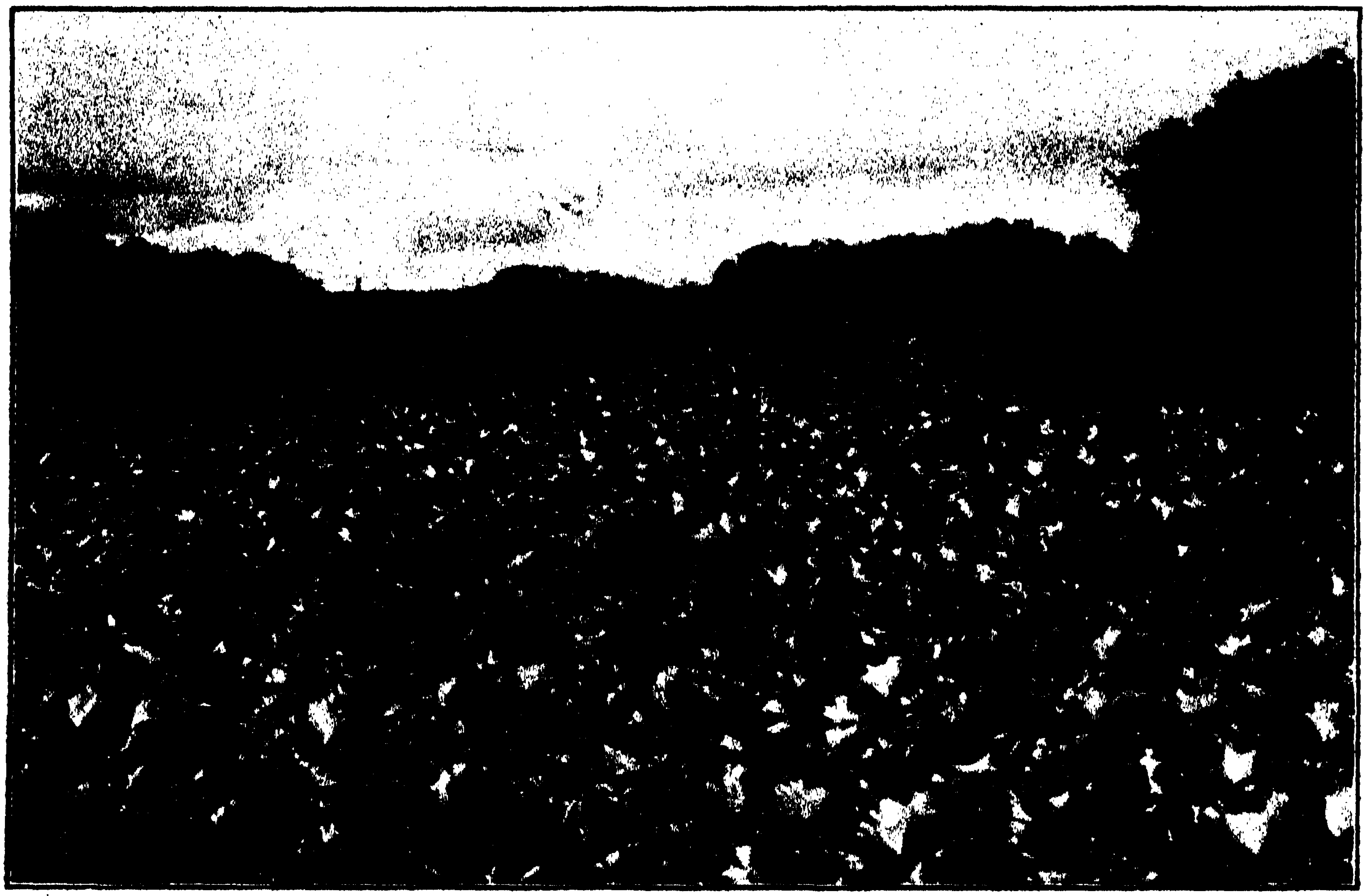
sufficiently high to furnish vegetable crops and citrus groves with capillary water in the pinelands and hammocks lying between the Everglades and the ocean.

The Everglades were not much traversed by the white man for a period of two generations in about the middle of the last century, or in other words, from the period of the notorious Indian hunters after the first big real estate grab was made more or less successful by an attempt to exterminate the Seminole or remove him from the land, down to the remarkable developments during the first quarter of this century.

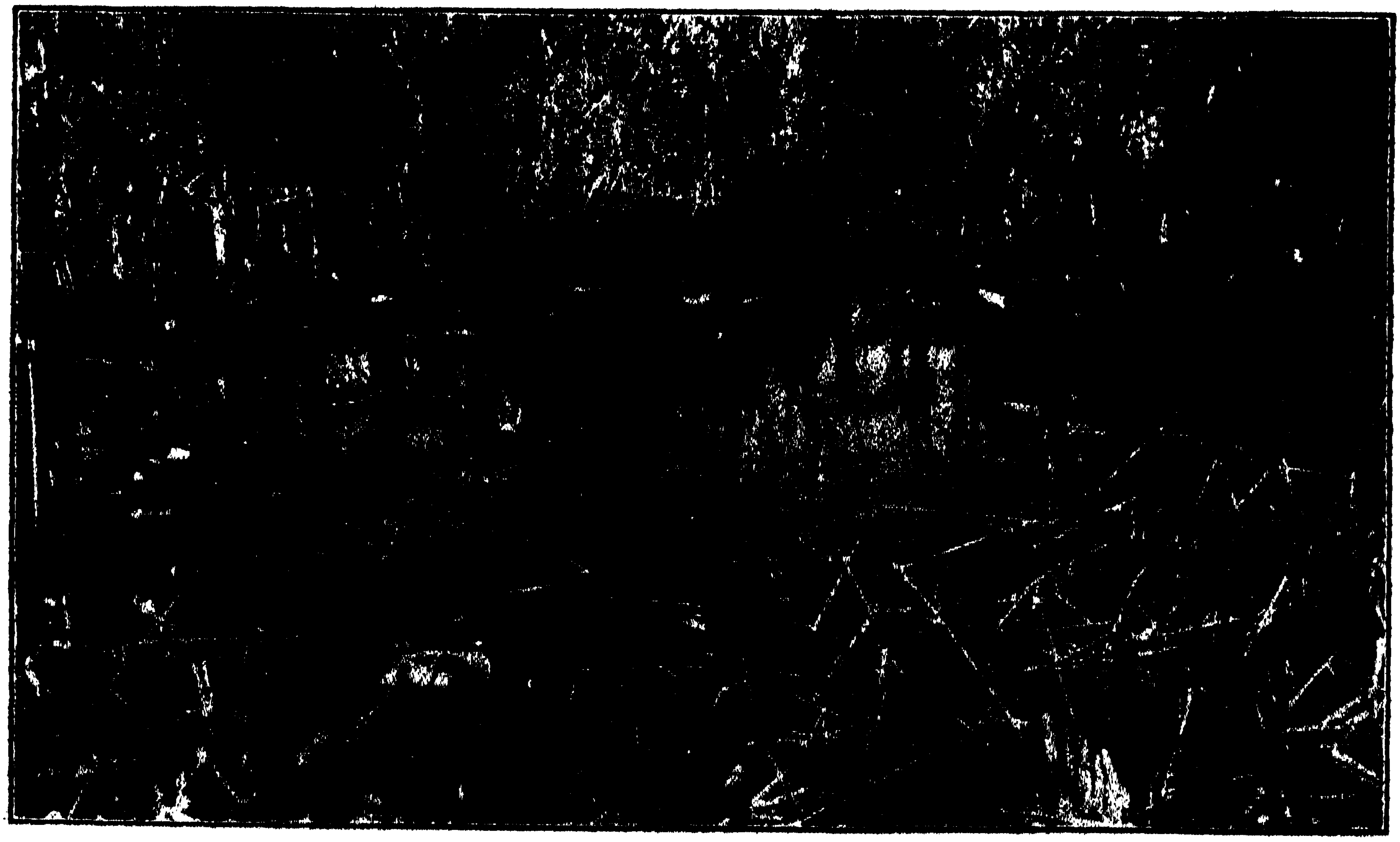
The Everglades have, or should we say once had, several floristic features. Their edges are fringed by such natural plant-associations as flatwoods, pinelands, small prairies, or "glades," and hammocks. The latter plant-association, truly a jungle, although really a minor element in the structure of the Everglade vegetation, gave to the general public through superficial observation the erroneous idea of the Everglades. Aboriginal mounds or ruins of aboriginal occupation and civilization are also to be met with on the outskirts and in the interior.

To one who has been through the Everglades, several major elements in its superficial geology and vegetation are evident. At the upper end there is a shallow basin which, always filled with water, constitutes Lake Okeechobee. As the aborigines sometimes termed it Mayami, it appears as Lake Mayami on some of the early maps of Florida. Lake Okeechobee has several features of interest. Its area is second to the largest fresh-water lake within the United States—Lake Michigan being the larg-

Creek-Seminole Indians in a temporary camp near the eastern edge of the Everglades. The group represents three generations in Cypress Tiger's family. They still use native plants for shelter (palm-thatch) and for flour (coontie).



A SLOUGH IN THE EVERGLADES. A FORK OF THE HEADWATERS OF TAYLOR RIVER WHICH FLOWS SOUTHWARD TO THE BAY. THE WATER, COVERED WITH LILY-PADS AND MAIDEN-CANE, ABOUNDS IN AQUATIC AND AMPHIBIOUS ANIMALS. THE BORDERING HAMMOCKS ARE THE ROOKERIES OF COUNTLESS WATER BIRDS OF VARIOUS KINDS.



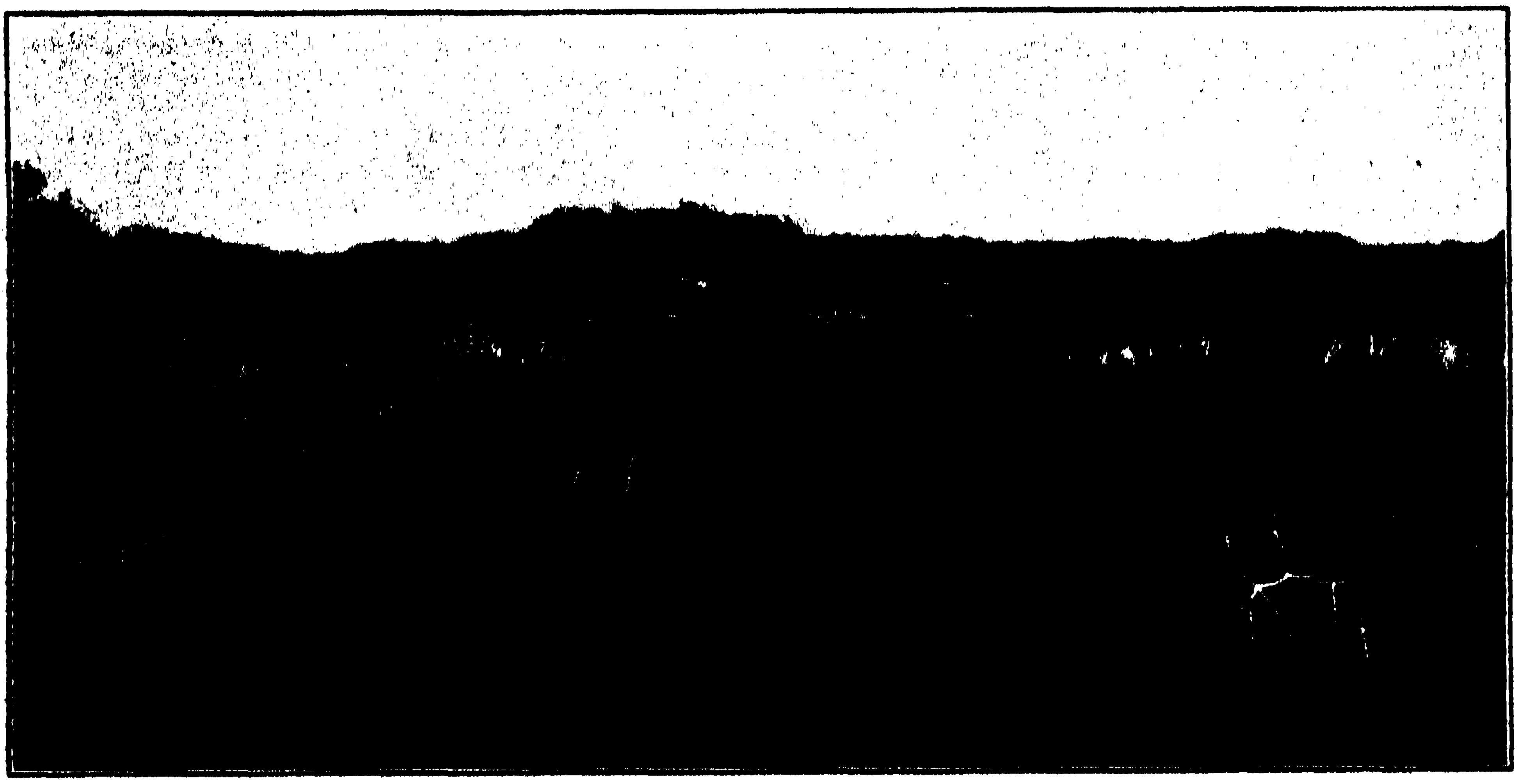
A "GATOR-HOLE" IN THE EVERGLADES. SUCH SHALLOW POOLS AND THE ENVIRONS ARE THE HOMES AND DELIGHTS OF THE ALLIGATOR. THE IMMEDIATE SURROUNDING PLANT ASSOCIATION COMPRISES SAW-GRASS, BULRUSHES, AND CAT-TAILS. LILY-PADS COVER MORE OR LESS OF THE WATER SURFACE.

est; it is a kind of counterpart of the celebrated St. Johns River. The headwaters of the St. Johns and those of Lake Okeechobee, the Kissimmee River, rise, the former on the eastern side and the latter on the western side of a rather narrow watershed. The St. Johns flows northward, expands with Lake George, continues and empties into the Atlantic Ocean through an easterly channel. The Kissimmee River flows southward, expands into Lake Okeechobee, and empties into the Gulf of Mexico through a westerly channel—the Caloosahatchee.

TEMPORARY CAMP OF CREEK-SEMINOLE INDIANS IN THE EVERGLADES. THE GROUP SHOWS JESSIE WILLY AND FAMILY. A CENTURY OF EXPERIENCES MAKES THE EVERGLADES A SAFE PLACE OF RESIDENCE FOR THE INDIANS. THEY MOVE ABOUT DRY-SHOD OR BY CANOE, ACCORDING TO THE STAGE OF THE WATER.

Up to a few years ago the rim of Lake Okeechobee, particularly on the eastern side where the strong westerly winds and hurricanes through ages had thrown up some of the lake bottom as a sand beach, a primeval forest—hammock—of gigantic cypress trees and various broad-leaved temperate-region trees, such as the maple, the ash and the elm, and a few tropical trees whose seeds had been sown there by migratory birds, formed a plant-association of indescribable beauty. On the southern side between the open waters of the lake and the Everglade prairie there had accumulated an enormous deposit of humus or decayed vegetable matter apparently unequaled by a similar structure in the United States. This accumulation of humus, essentially a gigantic sponge, covering thousands of acres varying from one foot to several feet in depth, supported an association of pond-apple and elder unique in all of North America. The Everglades south of Lake Okeechobee, say for half the distance to the Bay of Florida, are merely saw-grass prairie, with just the same amount of relief as mid-ocean in calm weather. In the more southern portion the surface is dotted by myriad hammock islands ranging from a small fraction of an acre to several acres in extent.[1]

[1] Some plant geographers consider the southeastern part of the Florida Peninsula lying south and east of the Everglade Keys as



WHERE THE EVERGLADE PRAIRIE MEETS THE BRACKISH AND SALINE MARSHES AND SWAMPS OF THE CAPE SABLE REGION. THOUSANDS OF ACRES ARE COVERED WITH DWARF MANGROVES AS SHOWN ABOVE. TOWARDS THE COAST THE MANGROVE TREES GROW VERY LARGE AND WITH THEIR PROP-ROOTS FORM IMPENETRABLE FORESTS.

Although Lake Okeechobee naturally has a nearly stable water-level, in the greater part of the Everglades the level of the surface-water has normally a seasonal fluctuation. Thus in the rainy season, the summer, the Everglades should be brimful of water; on the other hand, in the dry season, the winter, the surface should be more or less dry. At this period the Everglades represent a low prairie, while in the wet season they really constitute a vast lake. When seen at this high-water stage, some of the early Spanish expeditioners considered the whole basin a vast lake and it was recorded "Lake Mayami."

Various minds have conceived various schemes for the "development," of the Everglades, or "devilopment" as interpreted by some. Among these ideas "drainage" and "farming" have been prominent excuses for tampering with the Everglades, ravishing directly the "glades" and indirectly the whole of the southern part of the Florida peninsula.

Since the beginning of this century five water highways, preliminary to the dredging of drainage canals, have been added to the natural outlets for the enormous amount of water of this spring. The sudden upsetting of nature's routine of ages did not better matters, to say the least. Droughts and "freezes" are said to be now more frequent than formerly. Large areas of land between the Everglades and the ocean are said on good authority to have been rendered worthless for farming by seriously lowering the water-table and eliminating the capillary water-supply necessary for the existence of vegetation, particularly of cultivated crops. Thousands of acres of humus, deprived of the moisture naturally covering the rocky or sandy foundation of the Everglades, have completely disappeared in smoke, gases and

"Front Prairie." By position it is a front prairie, but in no essential way, either in structure, plants or plant-associations, does this one differ from that part of the Everglades lying north and west of the Everglade Keys, except where it is invaded by maritime vegetation.

NEAR THE SOUTHERN END OF THE EVERGLADES WHERE THE FORMATION OF THE BIG CYPRESS SWAMP INTRUDES FROM THE NORTHWEST. IN WINTER, THE MYRIAD DWARF LEAFLESS "EVERGREEN" POND-CYPRESSES RESEMBLE SO MANY SKINNY SPECTERS STANDING FOR MILES ACROSS THE PRAIRIE. THE TREES NEVER GROW PERCEPTIBLY LARGER.

scant ashes, thus turning the Everglades back to a desert just as it was when it was first elevated from the sea.

As some one has recorded: "There will be revelation for the North in the Everglades' conflagration, for millions regard these as but an immense swamp, and how could a swamp burn? Facetiously they may remark that the Everglades need irrigation rather than drainage. The blaze is serious, endangering thousands of acres of rich soil. The fire wardens' forces and others are fighting the flames, and drenching rains would be welcome. Careless hunters or motorists are blamed for starting the fire. No! the crazy drainage schemes are responsible. Nature's building of ages utterly destroyed in a decade!"

The Everglades were made for plants and animals to inhabit and delight in; not for man to occupy. This fact should have been evident to a mere tyro. Man could have enjoyed its uniqueness. When nature has turned loose hurricanes Lake Okeechobee and the surrounding Everglades have taken and will take a larger toll of human lives than the region of the same latitude exposed to the full fury of the ocean.

Aside from any indirect devastation caused by drainage, fire has destroyed the humus on many thousand acres. When once started in the dry humus, fire eats in and down, and burns until it reaches water or sand. Fires aerial and subterranean have eaten away many thousands of acres of pure humus in the Everglades during the past decade and the fires are still burning. The Everglades can safely be termed the "Land of Ten Thousand Smokes." Would it not have been a better plan to have closed this land to "devilopment" and had it appear on the maps of Florida as "Lake Okeechobee—Everglades National Park"?

THOMAS CHROWDER CHAMBERLIN

THE PROGRESS OF SCIENCE

THOMAS CHROWDER CHAMBERLIN

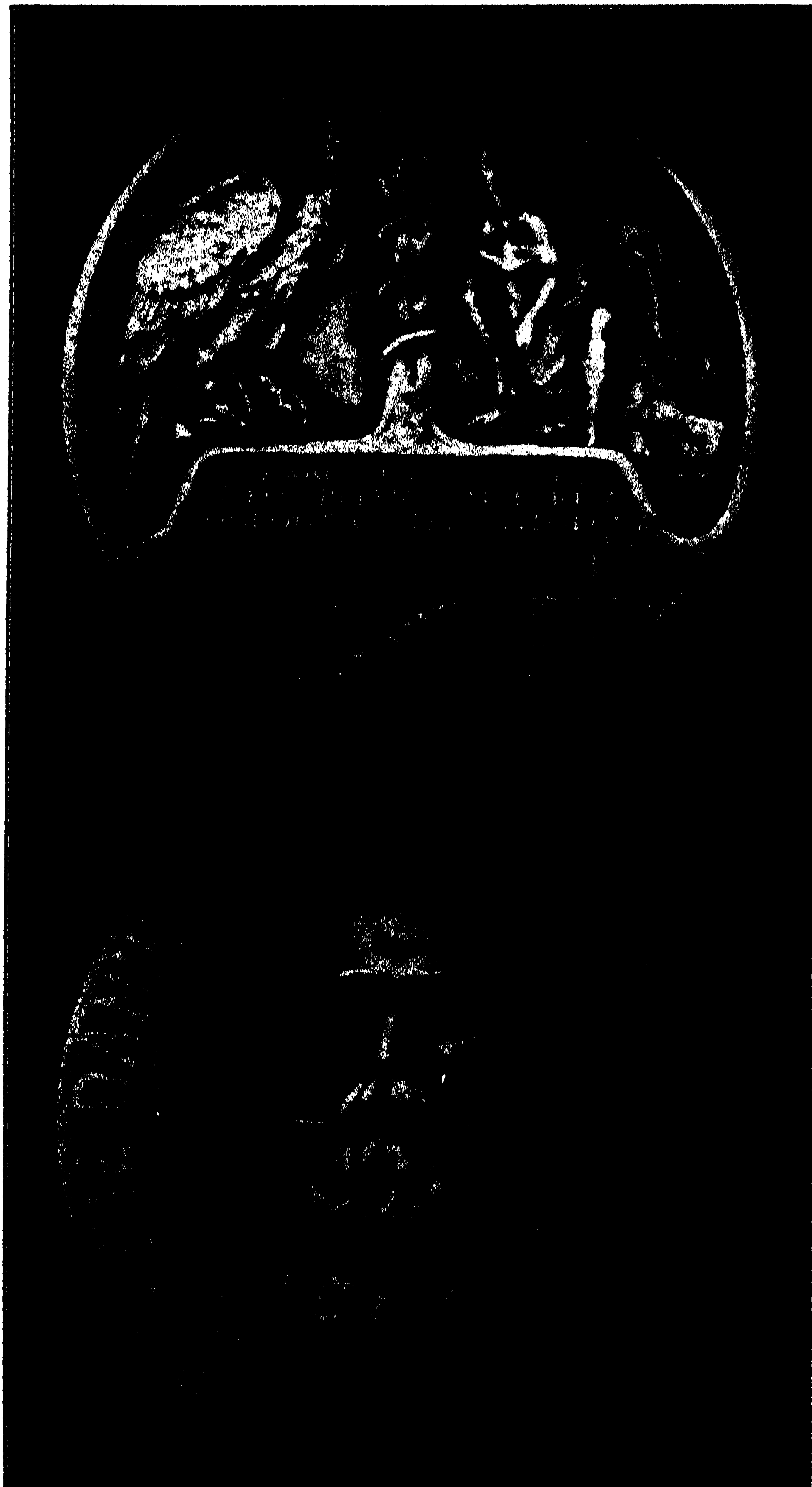
A MASTER of research has passed in Thomas Chrowder Chamberlin. His place is with the greatest thinkers of the past. He leaves few if any equals among his contemporaries. His far-flung research into the processes of the universe is a challenge to younger students to spread wings of imagination toward the unknown—but only with thorough understanding of the course to be flown and constant checking of the navigation.

Chamberlin, the glacialist, geophysicist and cosmogonist, was a geologist in that large meaning which he expressed at the Cleveland meeting, a year ago, in calling upon his colleagues to overleap the bounds of a petrified, terrestrial science. Rocks are not dead. They are to be studied as living assemblages of energy, organized according to the laws of physics and chemistry. He bade geologists explore these domains intensively, as their own. He invited them to penetrate the marvelous cosmogonies of the atoms, where in those intimacies of nature lies hidden the secret of evolution. He unrolled the history of the planet and traced our dynamic descent from our parent, the Sun. His concept of geology embraced the solar system and touched the stars. Fully aware that he could not long sustain the effort, he appealed earnestly to his fellows to carry on in all the fields of the science of which "astronomy is the foreign department."

Chamberlin will always be known as the author of the planetesimal hypothesis of the birth and growth of the Earth. Its fundamental concepts are wholly his. The mutual reactions of the Sun and a passing star in giving birth to the planetary system he reasoned from its orderly movements, as he has more recently argued the erratic origin of comets in the Sun's ungoverned, eruptive activity. These concepts are the survivors of a large number of possible inductions which he investigated, rigorously applying the method of multiple hypotheses. His endeavor was to find a process that would give rise to swarms of planetesimals from which the dynamic peculiarities of the planetary system might evolve. The initial idea of the growth of the planets by a gathering in of planetesimals was forced upon him by the failure of the gaseous and meteoritic assemblages of matter to meet the tests to which he and his collaborator Moulton patiently subjected them.

Some thirty odd years ago he compared the work in which he was engaged to that of a miner exploring an old mine to ascertain what of value might have been left in the old leads. It was not until he had proved them valueless that he turned to new prospects, which he exploited patiently, persistently and critically in discriminating search for the true vein of reality.

In collaboration with the colleagues whom he drew about him Chamberlin was dominant because of the tremendous mental power behind his thinking, but never by assumption of authority. He put forward every idea that his fertile mind conceived. Then he tested each one by natural logic, as his phrase was, and he expected his associates to test his suggestions by every pertinent critical fact or by mathematical analysis. He welcomed a justified destructive critique as clearing away an obstruction to advance. He constantly guarded himself and his fellow students against overconfidence in the verity of his assumptions.



THE DANIEL GIRAUD ELLIOT MEDAL

Shortly before the appearance of his last work, "The Two Solar Families," which reviews his previous work critically and presents supplementary deductions that strongly support the old, at the age of eighty-five, he wrote:

> The most friendly thing I can urge is that you look critically into my logic and my conclusions. I have, of course, great confidence that in all essentials I am in the line of reality, but it behooves others to discount any self-partiality that may creep into my work.

Unfortunately few are qualified by understanding of geology, geophysics and celestial dynamics to analyze, much less to criticize, Chamberlin's contributions to the science of the Earth and the solar system. His philosophy of geology will not bear its full fruitage until a generation shall have grown up free from the inherited theories that he discarded and open-minded toward the new ideas he has inspired.

Chamberlin's intellectual detachment from his own ideas was the more remarkable because he was a man of very strong convictions. He was most conscientiously convinced, however, of the inviolate integrity of truth, and he defended the truth, as facts presented it, from misrepresentation by himself as sternly as from attacks by others.

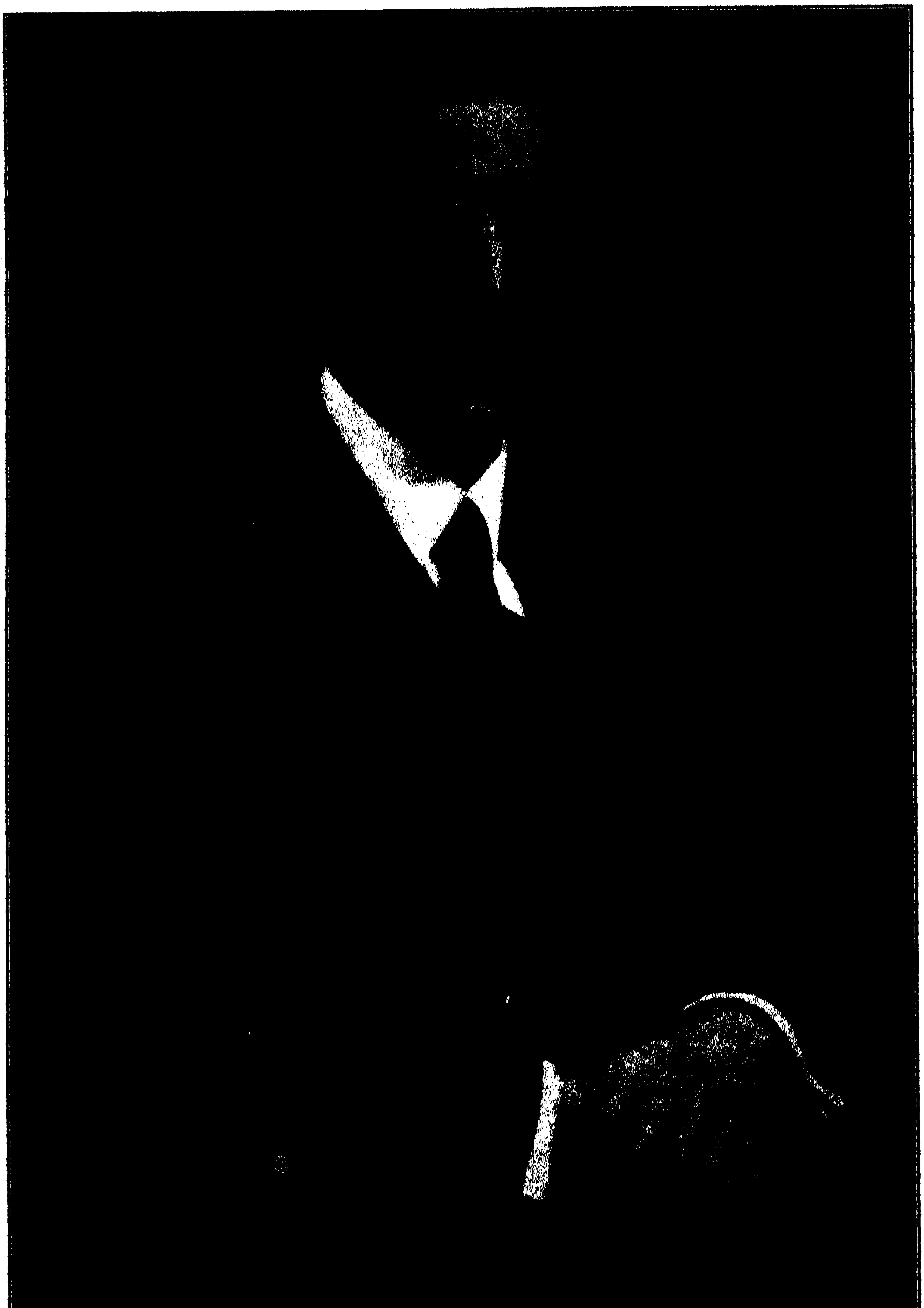
Of his wide range of contributions to science and of the man himself in his human relations this is not the place to speak. This is but a slight tribute to his greatness from one who has been privileged to walk by his side.

BAILEY WILLIS

PRESENTATION OF THE DANIEL GIRAUD ELLIOT MEDAL TO PROFESSOR EDMUND B. WILSON

BY the terms of the deed of gift of the Daniel Giraud Elliot Fund of the National Academy of Sciences, the income of the fund is to be applied to the striking of a gold medal "which together with an accompanying diploma and the unexpended balance of income for the year is to be awarded annually to the author of such paper, essay or other work upon some branch of zoology or paleontology published during the year as, in the opinion of the judges, who shall be Henry Fairfield Osborn, of New York, the scientific director of the American Museum of Natural History, and the secretary of the Smithsonian Institution, shall be the most meritorious and worthy of honor." Owing to the death of Dr. Walcott, chairman of the committee in charge of the fund, no award had been made since that of 1924. Dr. Frank R. Lillie has been appointed chairman in place of Dr. Walcott, and the judges have awarded the medal for 1925 to Professor Edmund Beecher Wilson in recognition of his monumental work on "The Cell in Development and Heredity," and for his many other important contributions to cytology. The chairman of the committee requested Professor E. G. Conklin to state the reasons for the award, in presenting Professor Wilson for the reception of the medal at the dinner of the academy at Schenectady on November 20, which he did as follows:

> Mr. President, I count it a great honor and privilege to present for the Daniel Giraud Elliot Medal a man whom we all delight to honor, one who is recognized throughout the world as a foremost authority in cytology, and one in whom unusual accuracy and precision of work is combined with breadth of view, critical judgment with sympathetic cooperation, the mind of a scientist with the imagination of an artist.
>
> The present science of cytology had its birth during the eighties of the last century, and the first edition of "The Cell" appeared in 1896, scarcely a decade after the epoch-making discoveries of Boveri and Van Beneden. It at once took first rank among books on cytology and contributed mightily to the development of that subject. The second edition appeared in 1900 in a revised and slightly enlarged form,



Bachrach

DR. CLINTON JOSEPH DAVISSON

OF THE BELL TELEPHONE LABORATORIES, ON WHOM THE NATIONAL ACADEMY OF SCIENCES HAS CONFERRED ITS COMSTOCK PRIZE FOR "THE MOST IMPORTANT RESEARCH IN ELECTRICITY, MAGNETISM AND RADIANT ENERGY MADE IN NORTH AMERICA DURING THE PAST FIVE YEARS."

and it has for more than a quarter of a century been a standard reference book in cytology. During this quarter century cytology made wonderful progress, especially in its relation to genetics. It was in 1900 that Mendel's law of heredity was rediscovered; only two years later Wilson and his students discovered that the cellular basis of Mendelian segregation lies in the separation of maternal and paternal chromosomes in the formation of the germ cells. Again in the year 1905 Stevens and Wilson proved that sex in certain insects is determined by the distribution of two kinds of sex chromosomes to two kinds of spermatozoa; if an egg is fertilized by one of these kinds males are produced; if by the other females result. This solution of the problem of sex determination has been found to be applicable, with certain modifications, to almost every class of animals and plants, thus disposing of one of the oldest and most perplexing problems in the whole realm of biology. Finally on the basis of this work Morgan and his associates, working in close relations with Wilson, have discovered not only the details of "the architecture of the germplasm" but also some of the most important features of the cellular basis of heredity, mutation and evolution. These discoveries represent the high points in the progress of biology in this century, and of all of them Wilson could truthfully say, though his well-known modesty would forbid, "All of which I saw and much of which I was."

The third edition of "The Cell in Development and Heredity" has been written out of this unique experience; it represents not only the mature point of view of the world's leading student and teacher of cytology, but it is to a large extent the work of its leading investigator in this field. Few other workers are left who were in at the birth of this science and who can speak of its development with the knowledge that comes from intimate contact with persons and problems, and no one could deal with this subject in a more comprehensive and judicial manner. Though called a third edition of the earlier work, this is in reality an entirely new book, rewritten from cover to cover and almost three times as large as the previous edition. It is in every respect a monumental work, one of the most complete and perfect that American science has produced in any field, and while we congratulate Professor Wilson upon this consummation of the work of a lifetime, we are proud of the fact that the National Academy of Sciences can bestow the Elliot Medal on a fellow member for a book of such outstanding worth as "The Cell in Development and Heredity."

THE ASTROPHYSICAL OBSERVATORY OF THE CALIFORNIA INSTITUTE OF TECHNOLOGY

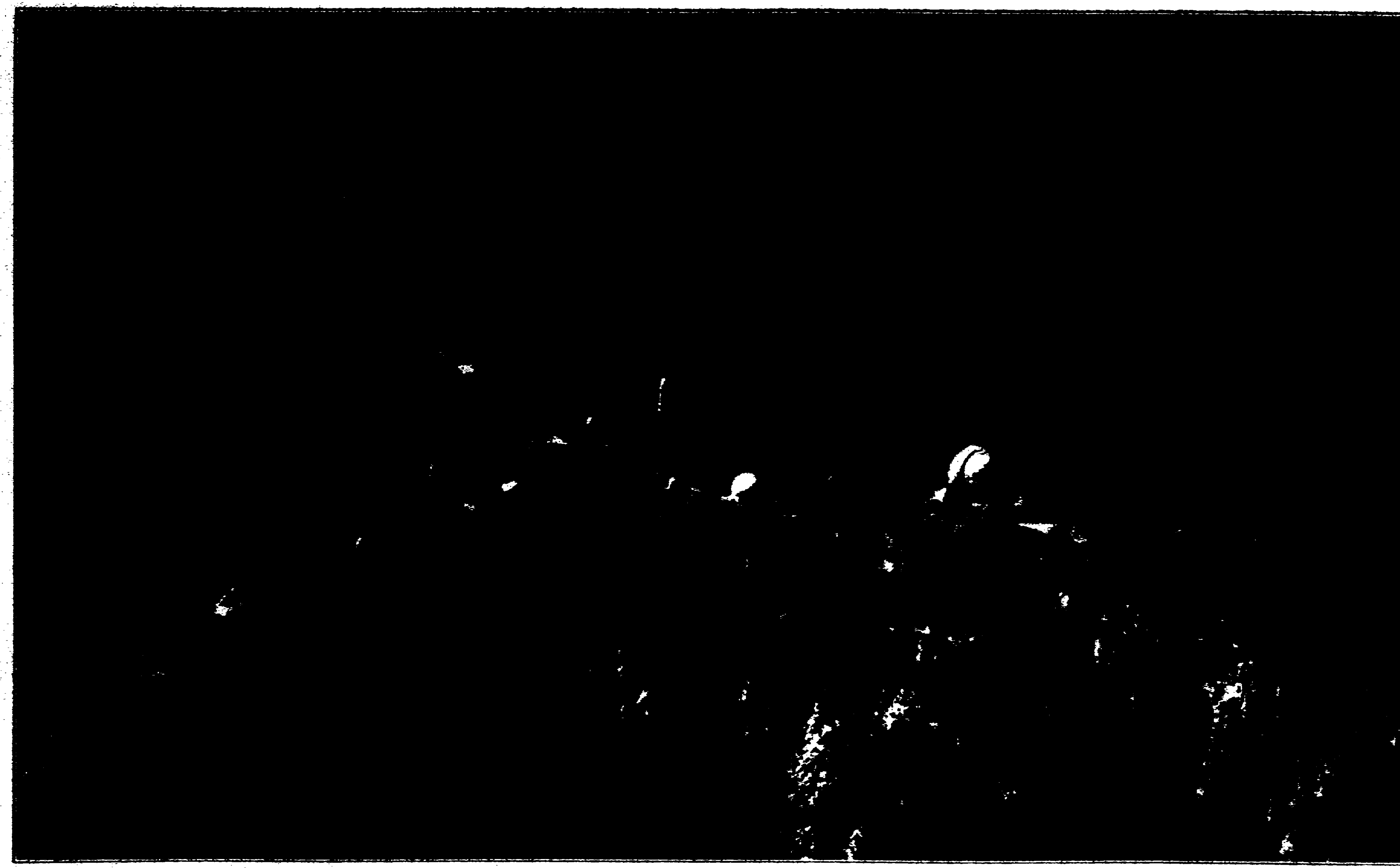
THREE research institutions, working in close cooperation, center in Pasadena: the California Institute of Technology, the Mount Wilson Observatory of the Carnegie Institution of Washington and the Huntington Library and Art Gallery. During the last six years the California Institute and the Mount Wilson Observatory have been conducting a joint attack on the physical, chemical and astronomical aspects of the problem of the constitution of matter, which has resulted in many fundamental advances.

A recent gift to the institute from the International Education Board will permit this attack to be greatly extended, and will provide for an equally wide extension of the various astronomical researches initiated and developed at Mount Wilson. Under the terms of the gift and the approval of their governing boards the Norman Bridge Laboratory of Physics, the Gates Laboratory of Chemistry and the Mount Wilson Observatory will work in the closest cooperation with the new equipment, which will be designed so as to supplement and not to duplicate the instrumental and other facilities already available.

Provision has been made for a 200-inch telescope, with mirror of fused silica instead of glass, to be erected at the most favorable high altitude site that can be found within effective working distance of the cooperating groups of investigators. An astrophysical laboratory, equipped for the measurement, reduction and interpretation of the

BERTRAM GOODHUE'S DESIGN FOR THE CALIFORNIA INSTITUTE OF TECHNOLOGY

THE DESIGN IS BEING FOLLOWED AS CLOSELY AS POSSIBLE. TWELVE BUILDINGS HAVE BEEN PROVIDED FOR. THE NEW ASTROPHYSICAL LABORATORY IS SHOWN.



AIRPLANE VIEW OF THE SUMMIT OF MOUNT WILSON

FROM LEFT TO RIGHT ARE THE SMITHSONIAN ASTROPHYSICAL OBSERVATORY, "MONASTERY," 10-INCH TELESCOPE, POWER HOUSE, LABORATORY, SNOW HORIZONTAL TELESCOPE, SMALLER TOWER TELESCOPE, LARGE TOWER TELESCOPE, 60-INCH TELESCPE AND 100-INCH HOOKER TELESCOPE.

photographic, spectrographic, radiometric and visual observations made with the new telescope, and for various other researches of the joint staff of investigators and the members of a graduate school of astrophysics, will be erected on the campus of the California Institute in Pasadena. The instrument shop will be in a separate building, also on the campus of the institute.

The trustees of the institute have appointed an observatory council, entrusted with the design, construction and operation of the new observatory and laboratory. Its members, chosen from the executive council of the institute, are Robert A. Millikan, Arthur A. Noyes, Henry M. Robinson and George E. Hale (chairman). Through the courtesy of the Carnegie Institution of Washington, Dr. John A. Anderson, of the Mount Wilson Observatory, has been appointed the executive officer of the observatory council, in direct charge of design and construction. In the determination of policy the observatory council will also be assisted by an advisory committee, comprising Dr. Walter S. Adams, director of the Mount Wilson Observatory; Professor Frederick H. Seares, its assistant director; Dr. Charles G. Abbot, secretary of the Smithsonian Institution; Professor A. A. Michelson, of the University of Chicago; Professor Henry Norris Russell, of Princeton University, and Professors Richard C. Tolman, Paul S. Epstein and Ira S. Bowen, of the California Institute. Many other astronomers, physicists, chemists, meteorologists, engineers and instrument makers in these and other institutions will be called upon for advice and assistance in connection with the design and construction of the buildings and instruments, and the selection of the best available site for the 200-inch telescope. Special attention will be given to the study and improvement of the auxiliary apparatus and devices required for the registration analysis, measurement and interpretation of celestial phenomena.

In the operation of the telescope the same policy will be maintained which has been followed in the past at the Mount Wilson Observatory and the California Institute of inviting leading authorities in astronomical and astrophysical research to use the 200-inch telescope in the extension of their investigations.

THE SCIENTIFIC MONTHLY

FEBRUARY, 1929

PRESENT TENDENCIES IN BIOLOGICAL THEORY[1]

By Professor WILLIAM MORTON WHEELER
BUSSEY INSTITUTION, HARVARD UNIVERSITY

> Ainsi, l'être vivant ne constitue pas une exception a la grande harmonie naturelle qui fait que les choses s'adaptent les unes aux autres; il ne rompt aucun accord; il n'est ni en contradiction ni en lutte avec les forces cosmiques générales; bien loin de là, il fait parti du concert universel des choses, et la vie de l'animal, par exemple, n'est qu'un fragment de la vie totale de l'univers.
> —*Claude Bernard.*

MOST scientific investigators are, no doubt, satisfied with the course of development and optimistic in regard to the future of their own specialties. There are always theorists, however, who, in an endeavor to view particular sciences as wholes, find cause for considerable dissatisfaction with their existing condition and tendencies, and biology is most liable to become the object of such disparagement, especially during periods like the present when the adjacent physico-chemical sciences are undergoing revolutionary and brilliant transformation. Some dwell on the deplorable "Zersplitterung" and dearth of adequate theory in the life-science (*e.g.*, Schaxel[2]). One erratic historian, Radl,[3] finds that biology has been steadily going to the dogs ever since the Renaissance, though it is clear, as Whitehead has noticed, that "the biological sciences as effective schemes of thought are barely one hundred years old."[4] Another recent theorist, Bertalanffy,[5] believes that biology has about reached a stage corresponding with pre-Copernican astronomy and physics, and maintains that the biologists have not yet discovered a single law, that what they have been fondly calling laws are merely rules or generalizations. He would probably regard the "biogenetic law" as little more than an inference or conjecture. As proof of his contention he instances the frequent naming of physical laws after their discoverers and the absence of this practice among biologists, except, of course, when they mistake mere rules for laws as in the case of Mendelism. Indeed, one infers that biologists, unlike physicists, do not understand the meaning of scientific legality and would not recognize a law if they saw one. Not only have they failed to secrete the proper theoretical cohesive for their in-

[1] Address given by invitation at a general session of the American Association for the Advancement of Science, American Museum of Natural History, New York, December 29, 1928.

[2] J. Schaxel, "Grundzüge der Theorienbildung in der Biologie," 2 Aufl. Jena, 1922, p. 1, ff.

[3] E. Radl, "Geschichte der biologischen Theorien in der Neuzeit," 2 Aufl. Vol. 1, 1913, p. 147, 161, 270, etc.

[4] A. N. Whitehead, "Science and the Modern World," London and New York, 1925, p. 141.

[5] L. Bertalanffy, "Kritische Theorien der Formbildung," Berlin, 1928.

numerable and highly heterogeneous data, but they are still addicted to the use of a medieval and Aristotelian glue compounded of such antiquated ingredients as Cartesian mechanics, potentialities, dispositions, determinants, instincts, impulses and purposes. And to increase our discomfort, we are warned by some theorists that unless we make haste and produce a few Einsteins who can furnish a sound scientific foundation for individual and social ethics, economics, politics and human genetics, our whole race will be asphyxiated under the flood of machines and other contraptions that keep pouring down on us from the fecund womb of technology. The theorists therefore speak of the present state of biology as a crisis, but they make it look more like a mess. Perhaps we ought to study the situation.

We must ruefully admit, I believe, that biology does present an appearance of extreme confusion. This is manifestly due in part to the inconceivable intricacy of the sector of reality which the biologists have undertaken to explore and partly to the situation of this sector midway between physics and chemistry on the one hand and philosophy on the other. This situation has both its advantages and disadvantages, and one of the latter is certainly the discomfort which the investigator, who is necessarily a specialist, suffers from exposure to so many winds of doctrine, blowing from such diverse quarters. Some of these winds, laden with the heady odors of relativity and atomic theory, now blow steadily from the domains of physics and cosmogony, while others, more intermittent, and saturated with staler effluvia, blow from the quagmires of epistemology and metaphysics, and, of course, we must not forget the odoriferous doctrinal gusts that are always rising from the more active portions of the biological field itself. How can we blame the investigator if he complains of the draughts and hurries away to the seclusion of his own specialty?

Yet the theorists may be right in censuring this behavior on the ground that the investigator needs the open air, even if it is not always very fresh. We are reminded that it is neither the observational and experimental data nor the investigational methods, but the theories that are the essential, vital constituents of a science. It would be easy to show that they can not be dispensed with, however circumscribed the problem of research, and it would be almost as easy to show that an abiding interest in the more comprehensive theories—those conceived in the grand manner—is all that prevents our sciences from lapsing into little more than empirical routines. I need hardly say that I am employing the word theories in this paper in a very broad sense to include also hypotheses, generalizations and fictions, as that word is used by Vaihinger in his philosophy of the "as-if," a polite substitute for the phrase "lies, damned lies and statistics." Since we seem to be justified in concentrating on the regnant theories of a science as the best expression of its tendencies during any particular period, the discussion may be largely confined to a consideration of some of the dominant theoretical interests in present-day biology.

We might divide the tendencies into three groups: those which biology in the broadest sense shares with all the other sciences, those peculiar to particular biological sciences and those that originate either in some one of the latter or in some non-biological science and tend to spread over the whole biological domain. Well-known tendencies common to all the sciences at the present time are, of course, the prodigious accumulation of empirical data and the intense specialization and differentiation of the methods and devices for penetrating reality that are demanded by the investigator's urge for more critical

analysis of phenomena. The tendencies in the various biological sciences exhibit extraordinary diversity. Some of the older sciences, like taxonomy, have become largely routine accumulation of data and their discriminative refinement and systematization, while others, like genetics, are heaving with instability and display what Schaxel has called "eine theoretische Verwilderung." In some of the sciences the births and deaths of hypotheses succeed one another with truly modern, if not always commendable speed, while the hypotheses that can maintain their vigor seek to preempt as much as possible of biological thought. Some of these hypotheses are, of course, emulative, fanciful or merely imitative, but probably none of them is altogether useless. There are also what might be called negative tendencies, such as the deficiency of historical sense, which characterizes our whole civilization and may be due, as Tilgher has suggested, to the gradual rising to control of a new social class, the proletariat, just as the eighteenth century's neglect of history was due to the rise of the bourgeoisie.

Sociology
Psychology
Anthropology
Ethology
Pathology
Physiology
Genetics
Morphology
Paleontology
Biogeography
Phylogenetics
Taxonomy

It would be impossible in the time at my disposal even to catalogue the more important theories that are peculiar to the various biological sciences, and I am surely incompetent to discuss them. All I can attempt is a rather impressionistic sketch of the theoretical conceptions that have had sufficient vitality, enterprise and generality to dominate large portions of the whole biological field. This sketch will acquire somewhat sharper contours if we begin with a list of the dozen odd biological sciences, arranged according to their more obvious affinities.

It will be granted that all these sciences have acquired considerable independence notwithstanding their complicated interrelations and that they might best be represented diagrammatically in the three dimensions of space. For my purpose, however, a simple serial arrangement will suffice, with sociology

Taxonomy
Phylogenetics
Biogeography
Paleontology
Morphology
Genetics
Physiology
Pathology
Ethology
Anthropology
Psychology
Sociology

and psychology, if we insist on their inclusion, at the top and phylogenetics and taxonomy at the bottom. But any arrangement of this kind at once arouses our sense of values, if only because first and last suggest superiority and inferiority. The sociologists and psychologists would say that this arrangement is quite acceptable, though they might differ as to which of their

respective sciences should head the list. The physiologist, too, might be satisfied and contend that his science is naturally at the very heart of the whole series, or he might liken the list to a ladder extending from the earth's interior to the heavens, with the sociologists and psychologists among the clouds, the taxonomists and phylogeneticists in the waters under the earth with the other blind fish, and himself alone with his feet solidly planted on the lithosphere. The dissatisfied taxonomist, however, might insist that the whole series should be inverted and likened rather to the ascending scheme of the Divine Comedy. He might say that the writhing and vociferous psychologists and sociologists should be consigned to the Inferno, that the physiologists and their neighbors, the geneticists, belong together with their caged and vivisected animals in the Purgatorio and that the taxonomists alone abide in the opalescent effulgence of the Paradiso among the Platonic ideas and essences which from time to time deign to descend as the species and genera to incorporate themselves in the organic individuals. Fortunately, we

Sociology **Psychology** Anthropology Ethology Pathology **Physiology** Genetics **Morphology** Paleontology Biogeography **Phylogenetics** **Taxonomy**

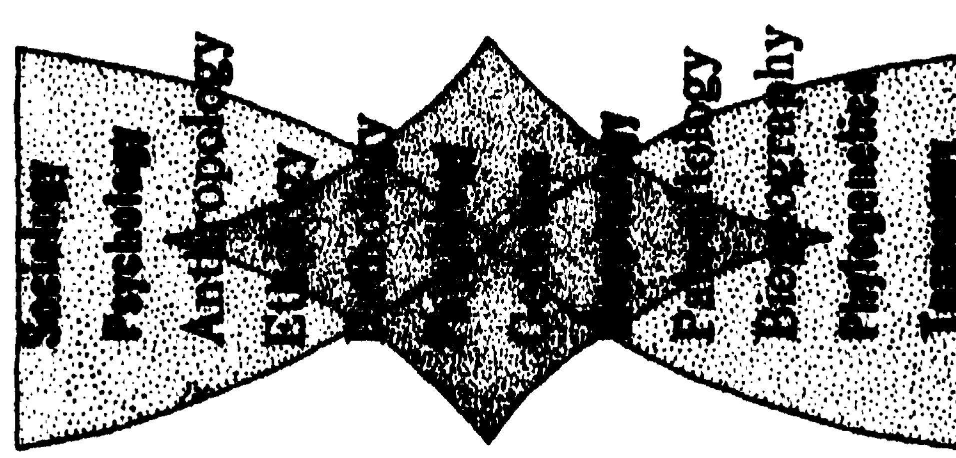
can avoid these unhappy evaluative dissentions by simply turning our original series through an angle of 90° and likening it in its new position to a spectrum, an advancing army or a parliamentary body with a right, conservative wing (taxonomy and phylogenetics), a left, radical wing (sociology and psychology) and a Catholic center (physiology and genetics).

I shall not deny that all this seems fanciful, or even puerile, but I wish to use the horizontal list, which places the biological sciences on the same level, as a background for more serious considerations, which it seemed best to approach by first eliminating some of the superficial emotional antagonisms that appear to be fostered by our traditional hierarchical arrangement. It will be noticed that the names of one half of the sciences are printed in heavy, the other half in lighter type. This is not for the purpose of emphasizing another evaluative distinction, that of importance and insignificance, but to call attention to the difference between the pure and mixed sciences. The former are often the older and are clearly the more independent in their general theoretical structure. Taxonomy, indeed, is quite independent, because it is the one biological science that has no theory, being merely diagnostics and classification. Modern taxonomy does, of course, assume a new significance in the light of evolutionary theory borrowed from phylogenetics, but it would probably have reached its present stage of development if that theory had never been thought of. Phylogenetics, morphology, physiology, psychology and sociology have clearly marked leading theoretical conceptions which are epitomized in the terms "history," "structure," "function," "mind" and "society," whereas the remaining biological sciences derive so much of their theory from their neighbors in the series, that they may be called mixed or blended sciences. Thus genetics combines morphology and physiology with an obvious though somewhat negativistic relation to taxonomy and phylogenetics; ethnology, or ecology as it is usually called, mixes physiology, psychology, morphology and phylogenetics; biogeography combines taxonomy, ethology, paleontology and phylogenetics; paleontology is a mixture of taxonomy, morphology, phylogenetics and ethology. In pathology the morphology, physiology, psychology and

phylogenetics of diseased organisms are combined, and anthropology may be regarded as a mixture of nearly the whole series of the biological sciences in so far as they have theoretical material applicable to man. The origin and splendid development of genetics within the past three decades suggest that other mixed sciences may arise in the future.

Each science is characterized by its theoretical constitution and this is, of course, conditioned by the peculiar interests of the investigator and the particular sector of reality to which they are directed. It is not surprising, therefore, that the sciences should be afflicted with an extraordinary number of logical oppositions, dilemmas, or contingencies between their theories. Some of the oppositions may be very persistent while others are capable of resolution or composition as soon as a higher or more synthetic theory has been excogitated to include them by a process not unlike that of the resolution of opposed statements or propositions in dialectics, on the principle that resolution is always possible between oppositions but never between contradictions.[6] Thus the formerly opposed theories of light and electricity in physics have been harmonized and the conflicts between the whole sciences of physics and chemistry are being smoothed out in recent atomic theory. A similar resolution seems to be imminent between physiology on the one hand and chemistry and physics on the other. Of course, the most acute contingency in biology is that between psychology and the other sciences and its resolution is not in sight, though some of the behaviorists are struggling to bring it about. Many less flagrant oppositions might be cited, such as that between the theory of the inheritance of acquired characters in phylogenetics and the present theories of genetics; within morphology, that between the static typology of comparative anatomy and the dynamic typology of experimental embryology; within phylogenetics, that between the monophyletic and polyphyletic theories of descent, etc. In all these cases it may yet be possible to invent more comprehensive theories that will compose the contingencies and from which the opposed theories may be deduced. The whole matter of the logical contingency of theories is very complicated, as Adolph Meyer has recently shown in a valuable but rather abstruse essay.[7] I have touched on it here, because it is illustrated by the dualism between certain ideas or orientations that have an important bearing on the biological sciences as a whole.

I return to our horizontal list which I have covered with two gray, partially overlapping areas as a rough visual indication of the distribution and dominance of these two ideas in the biological parliament. It will be seen that the



darker is concentrated in physiology and the immediately adjacent sciences, experimental morphology, genetics and pathology, and rapidly dwindles away towards the two wings. It may be taken to represent theoretical preoccupation with inframicroscopic reality. The larger area is much constricted in the center and spreads rapidly towards either end and may be taken to represent preoccupation with larger and larger microscopic and macroscopic entities. At the extreme wings these may

[6] See M. J. Adler, "Dialectic," New York and London, 1927, p. 188.

[7] A. Meyer, "Kontingenzerscheinungen an naturwissenschaftlichen Theorien," Symposion 1, 1926, p. 233–268.

be very comprehensive, as, *e.g.*, in taxonomy, with the whole existing fauna or flora or the whole biota considered as a unit, or in sociology with the whole Great Society, or the human race regarded *sub specie societatis.*

The same diagram may be used to illustrate the scope of two other more important contingent conceptions, or ideas, which have been emphasized by a whole school of German philosophers and historians, comprising Windelband, Troeltsch, Simmel, Rickert,[8] Münsterberg, Mehlis,[9] Kroner[10] and Meyer,[11] who designate them as the ideas of historism, or the idiographic and naturalism, or the nomothetic. To some of these writers they represent the two most significant directions of modern thought. Their differences are best illustrated by the sharp contrast between the investigative orientation of the historian and that of the physicist. The historian is interested in individuals and therefore in unique, more or less irrational, temporal manifestations of the real and in the values and purposes they assume, especially in their social and cultural relations. Since his investigations are confined to the past he is debarred from experiment and since he centers his attention on the qualitative, rather than on the quantitative, he can dispense with mathematics and employ verbal description, devoid of a special, technical vocabulary. He is more or less intuitive and may be said to be in search of meanings and symbolisms rather than causality, so that his conclusions are interpretations rather than explanations. The physicist, on the contrary, is not interested in the individual and unique, but in the general, or universal, quantitative and therefore measurable aspects of phenomena. He ignores the irrational, evaluative and purposive and confines himself to a purely rational explanation of the recurrent uniformities, or laws of reality, which he determines by analytical experiment and expresses in the exact language of mathematics. These schematic differences between the idiographic and nomothetic approaches to actuality have been greatly amplified in the works of the authors to whom I have referred and especially in Rickert's erudite treatise, which is now a classic. They have used the contrast to justify a dichotomy of the sciences into *Geisteswissenschaften* (history, sociology, psychology and philosophy) on the one hand, and *Realwissenschaften,* or natural sciences on the other. It is admitted, however, that biology is a hybrid in which both idiographic and nomothetic tendencies struggle for expression. Recently Kroner and Meyer have discussed the situation in this science, and Kroner has shown that the "historic" aspects of geology and cosmogony do not really fall within the idiographic scheme.

Although the general validity of the two contingent ideas has been questioned, especially by Tönnies,[12] Cassirer[13] and Höffding,[14] they do seem to divide

[8] H. Rickert, "Die Grenzen der naturwissenschaftlichen Begriffsbildung," 3. u. 4. Aufl. Tübingen, 1921.

[9] G. Mehlis, "Lehrbuch der Geschichtsphilosophie," Berlin, 1915.

[10] R. Kroner, "Zweck und Gesetz in der Biologie. Eine logische Untersuchung," Tübingen, 1913, and "Das Problem der historischen Biologie," Berlin, 1919.

[11] A. Meyer, "Logik der Morphologie im Rahmen einer Logik der gesamten Biologie," Berlin, 1926.

[12] F. Tönnies, "Gemeinschaft und Gesellschaft," 3. Aufl. 1920; see also A. Riehl, "Zur Einführung in die Philosophie der Gegenwart," 3 Aufl. Leipzig, 1908, p. 182; and P. Barth, "Die Philosophie der Geschichte als Sociologie," 1. Teil, 3 u. 4 Aufl. Leipzig, 1922, p. 32, *ff*.

[13] E. Cassirer, "Substance and Function and Einstein's Theory of Relativity." Transl. by W. C. and M. C. Swabey. Chicago and London, 1923, p. 221, *ff*.

[14] H. Höffding, "La Relativité Philosophique." Trad. par J. de Coussange. Paris, 1924, p. 135, *ff*.

the biological domain somewhat as represented in my diagram by the dark and light gray areas. Nevertheless, since biologists of all persuasions are really closer to one another than they are to the philosophers, chemists and physicists, the nomothetes have become infected with historism and the idiographers with naturalism. The language of both parties, therefore, is often so confused as to elicit from the epistemologists and theorists very disparaging remarks like those reported in the first paragraph of this paper. It is worth noting in this connection that the theory of evolution, or transformism—the only theory in the really grand manner that biology has given to the world—is obviously historistic and a creation of the idiographers. It has profoundly influenced even the philosophers and historians and is now invading atomic speculation. It is not surprising to find, therefore, that the physiologists often use such words as "organ," "function," "organism," "adaptation," "genesis," "heredity," "development," which certainly do not belong to their proper nomothetic, but to the idiographic, or historistic idiom. Of course, the physiologists might say that they use such language only when they are talking in their sleep or under the influence of anesthetics. The idiographers, on the other hand, feel that they have a perfect right to use nomothetic language, though they avoid it as a rule, not because it offends against good taste, but because it is too concise to serve as a medium for their own more exuberant lucubrations. It is only when a true philosopher like Hans Driesch enters the biological pasture that the idiographic sheep and nomothetic goats are made to realize the full iniquity of their contingencies. He informs the sheep that they are really woolly teleologists and the goats that they are nothing but hairy mechanists, and that he can make them all lie down and ruminate together if they will only permit him to bring in some of his queer creatures, the entelechies and psychoids, from the metaphysical barnyard to act as go-betweens. The metaphor is so distressingly bucolic that perhaps I had better try to express my meaning in less capricious language.

Driesch, Bergson and other vitalists were keenly aware of the dilemma that had developed between our historistic and naturalistic orientations. To Bergson it wore the guise of an opposition between intuition and intelligence, while Driesch, who was in closer touch with the biological situation, was more impressed by the old conflict between teleology and mechanism. We are now convinced that both of these popular word-realisms, the one imported into biology from philosophy, the other from Cartesian physics, are little more than fetishes. While the nomothetes among the biologists were prostrating themselves before Mechanism, some of the more bolshevistic physicists very stealthily carried it off and dropped it into the sea. Most of the physicists, of course, keep mum about the matter, but occasionally one of them may be heard to berate the nomothetes who still long for their tin deity. Thus even Professor Whitehead,[15] gentlest and most courteous of mathematician-philosophers, after referring to the various scientific idols that have lately been stolen from their worshippers, is moved to exclaim with a touch of irritation: "What is the sense of talking about a mechanical explanation when you do not know what you mean by mechanics?" And so conservative a physicist as Professor Bridgman[16] seems to imply that any of his fellow physicists who are still tempted to cry for their old image had better hurry to the con-

[15] *Loco citato*, p. 23; see also Schaxel, *l.c.*, p. 158.

[16] P. W. Bridgman, "The Logic of Modern Physics," New York, 1927.

fessional. He says: "I believe many will discover in themselves a longing for mechanical explanation which has all the tenacity of original sin. The discovery of such a desire need not occasion any particular alarm, because it is easy to see how the demand for this sort of explanation has its origin in the enormous preponderance of the mechanical in our physical experience. But nevertheless, just as the old monk struggled to subdue the flesh, so must the physicist struggle to subdue this sometimes irresistible, but perfectly unjustifiable desire." Driesch's first mistake was that of accepting the mechanistic theory at its face value. Then he went astray in construing the phenomena of regulation and adaptation as manifestations of teleology, or design. He therefore set about the conciliation of the animals in the biological pasture in the wrong manner. He should have told the goats that they were miserable sinners and the sheep that they were sentimental softies and have preserved a discreet and absolute silence in regard to the entelechies and psychoids that were quietly munching ectoplasm and other spiritual fodder in the transcendental corral.

It is well known that vitalism has many more lives than the proverbial cat and that it periodically invades and confuses biology, introducing its metaphysical entities for the purpose of resolving theoretical conflicts, just as the gods were brought down in the machine to straighten out the plots of the Greek drama. That we have again entered on a period that abhors such artifices is shown by the literature, in which references to Driesch's entelechism, the most serious and elaborate attempt ever made to provide biological *dei ex machina,* are becoming increasingly rare. The same is true of Bergson's "élan vital," which naturally played a greater rôle in philosophy. We still have on our hands, therefore, the contingency between the historistic and naturalistic ideas, and the question arises as to whether there are any means of overcoming their opposition. I believe that there are at least three recent theories, which, with some mutual adjustment, might yield a provisional synthesis, or at any rate clarify the conflict. These are the theory known as emergence, or "holism," the configuration, or "Gestalt," theory and behaviorism. The first had its origin in epistemology, the second in psychology and the third in ethology. The theory of holism, first elaborated by Alexander,[17] C. Lloyd Morgan,[18] and Smuts,[19] and recently approved by Höffding,[20] Oskar Hertwig,[21] R. B. Perry,[22] Lovejoy,[23] Bertalanffy,[24] Ritter and Bailey,[25] and others, starts from the consideration that the properties of a whole, as distinguished from a mere aggregate, sum or collection, though determined by the interrelations and interactions of the parts, are nevertheless novel and, except after previous knowledge of the mode of composition of the parts, unpredictable.

[17] S. Alexander, "Space, Time and Deity," 2 vols., London and New York, 1920.

[18] C. L. Morgan, "Emergent Evolution," London and New York, 1926.

[19] J. C. Smuts, "Holism and Evolution," London and New York, 1926.

[20] *Loco citato,* p. 42, 160.

[21] O. Hertwig, "Das Werden der Organismen," 3. Aufl. Jena, 1922.

[22] R. B. Perry, "General Theory of Value," New York and London, 1926.

[23] A. O. Lovejoy, "The Meaning of Emergence and its Modes," *Journ. Philos.,* Studies 2, pp. 167–189.

[24] *Loco citato.*

[25] W. E. Ritter and E. W. Bailey, "The Organismal Conception, Its Place in Science and its Bearing on Philosophy," Univ. Calif. Publ. Zool., 31, 1926, p. 307–358. For additional bibliographic references to emergence see my booklet, "Emergent Evolution and the Development of Societies," N. Y., W. W. Norton & Co., 1928. Professor Lovejoy has called my attention to an early, lucid statement on emergence in Maudsley's "Body and Will," 1884, p. 132.

That this "creative synthesis" is an empirical fact is shown by all chemical compounds and may be generalized to include all wholes, atomic, molecular, colloidal, cellular, organismal, psychical or social. There seems to be no good reason why we should not throw in also such astronomical wholes as the suns, planets, comets, solar system and galaxies for good measure, though we may have to stop this side of the universe because we can never know whether it is an emergent, even if it should prove to be a whole.

In all these existants we behold an inexplicable "social" tendency for wholes to combine and cooperate with wholes to form wholes of higher orders, or "levels," with new emergent properties. It appears to follow that at each level laws become operative which can not be formulated for emergents of lower levels, though the converse is not necessarily true. Hence the causes, or uniform functional relationships with which the biologist *sens. str.*, the psychologist and sociologist are concerned, differ from those of the physicist and chemist, though the physicochemical laws are not annulled even in such singular emergents as the organisms. All this is such a commonplace that its significance was overlooked till quite recently. The novelty stressed by the writers who have expanded this commonplace of emergence into a theory of creative evolution is evidenced by the psychical shock, or feeling of surprise which we experience when confronted with the individual emergent.

The Gestaltist, or configurationist, is also dealing with wholes, but he is more interested in their peculiar irreducibility as patterns either in space or in time than in their novelty. As illustrations he points to such wholes as are represented by identical designs in different colors on a uniform background, or the same melody played in different keys. In these cases the configurations must be due to the interrelations of their component parts, because these are very different in the same configurations. Behaviorism, both in its general, ethological form and in the radical form which it has been given by Watson, is also concerned with wholes, *i.e.*, with the action-patterns of the whole organism in response to its environment. But it is not so much the novelty or the configuration of this response *per se* as its regulative and adaptive character that interests the behaviorist. No recent tendency has been so successful as behaviorism, since it has affected the attitude of investigators in nearly every one of the biological sciences. The physiologist, pathologist, psychologist, anthropologist and sociologist have all been profoundly influenced, and even students of paleontology and phylogenetics are now adopting the behaviorist's point of view.[26]

Emergence, configuration and behaviorism are so similar that we may regard them as so many partial aspects of the single conception which has been called "organicism." The individual organisms, which constitute the only materials of biology, are certainly very peculiar emergents. They may, of course, be described as spaciotemporal events or as equilibrate systems but such descriptions seem singularly depauperate to the biologist, who prefers to regard them as very highly integrated, organized wholes endowed not only with the marvelous capacities of growth, development and reproduction but also of accumulating and registering the significant results of their own adaptive

[26] See in this connection H. Karny, "Die Methoden der phylogenetischen (stammesgeschichtlichen) Forschung," in Abderhalden's "Handbuch der biologischen Arbeitsmethoden," Abt. 9, 1925, p. 211–500, 51 figs., and B. Dürken and H. Salfeld, "Die Phylogenese. Fragestellungen zu ihrer exakten Erforschung," Berlin, 1921.

experience and of that of their ancestors over enormous periods of time and of deploying at least a distorted epitome of these results in their successive generations. They are, indeed, historical beings, as Boveri[27] maintained. The investigative orientation and methods of the historistic biologist as such, therefore, required no justification.

The peculiarities of organisms are surely sufficiently extraordinary to make them the objects of an independent, unitary group of sciences, biology, but all recent researches have shown that they are not sufficient to warrant appeals to mystical "organizatory factors," "instincts," "souls" and "social minds" to account for them. In as much as the novel organic emergents are due to the interaction of their parts it is necessary to investigate these parts and their interrelations if we are to have even a partial explanation of the whole which they constitute. Hence the nomothetic biologist is also thoroughly justified in his analytic physicochemical attitude and procedure. Regarding things as wholes, no matter how much aesthetic satisfaction or mental repose one may derive from their contemplation, is not scientific explanation. I conclude, therefore, that there is no conflict between the idiographers and the nomothetes among the biologists *sensu stricto*; they are merely working on two different levels, the physicochemical and the organismal. But organisms have also developed two other levels, those of mind and society, and it is the intrusive theories of their devotees, the psychologists, sociologists and philosophers, that disturb the harmony of the biological flock. Only those biological historists, therefore, who affect these theories, should be shorn of some of their wool to make them look more like goats. I allude, of course, to such lanuginous conceptions as "individuality," "value," "purpose" and "potentiality."

Theoretical conceptions have instrumental significance only on the phenomenal level to which they belong and become little more than word-fetishes when employed as explanations at other levels. This is obvious when philosophical, psychological and sociological notions like those just mentioned are carried down to the organismal and physicochemical levels. For example, individuality, in the sense of uniqueness, loses much of its mystery in biology since it is seen to increase at each higher emergent level as a function of the increasing multiplicity, interaction and integration of the parts in the whole, so that an atom will naturally have very little, an organism much more and a human personality a great deal of uniqueness. The irrationality and indefinability of the individual, which have such a mesmeric effect on the historists of the Rickert school and on many philosophers, are really aspects of the emergent as a novelty. In another sense, that of temporal and spacial persistence, individuality is implied in the whole as an integration or organization of parts. Some writers, notably Roux and more recently Whitehead[28] and Höffding,[29] if I understand them correctly, regard mere persistence or survival as the fundamental peculiarity of "value," but the petering out during the past seventy years of the theory of the survival of the fittest, in which this conception of value is implicit, shows that it is far too vague or philosophical to be of any use to the biologist. This was to be expected, because the theory of the survival of the fittest, or natural selection, really came to us from two sociologists of the old evaluative school, Herbert Spencer and Malthus. Of course, the ever-increasing tendency to

[27] T. Boveri, "Die Organismen als historische Wesen," Festrede 320. jähr. Bestehens Univ. Würzburg, 1906, 33 pp.

[28] *Loco citato.*

[29] *Loco citato.*

purge the biological sciences, including psychology and the new sociology, of all "values," does not imply that these may not be extremely significant in such purely hoministic sciences and pseudosciences as aesthetics, logic, ethics, economics, history, metaphysics and theology.

Potentiality, or possibility, is another philosophical notion that could hardly fail to be taken over by the historistic biologists when they began to study the ontogenetic development of organisms. It has persisted, under various disguises, since Aristotle—among the scholastics as the "virtues" or "occult qualities"; later as "preformation," or "evolution," in the old sense, and more recently as the "germplasm" in theories of Weismann and his school. Here the notion was elaborated in such detail that it soon revealed its true nature—the passing off of the photograph of a problem as its explanation. When experimental embryology got under way there was still much talk of "prospective potencies," or possibilities, but the emptiness of these conceptions soon became apparent, and the words "predetermination" or "Anlagen" were substituted. In this case we again see the gradual supersession of a misplaced philosophical by a useful, though not very precise, scientific concept. One often has the impression, however, that the dormitive virtues which Molière satirized are still soporific, not only in the literature of genetics but also in that of comparative psychology where they are called "instincts." In the meantime the dialecticians inform us that the realm of possibility is the peculiar and exclusive province of the philosophers, whereas the proper province of science is actuality. If I understand Adler correctly, the realm of possibility is so inexhaustible, that the philosophers can keep up disputation within its confines till the end of space-time and then start all over again. We should, therefore, generously hand over to them all the biological possibility we can collect and felicitate them on the prospective potency of their useful occupation.

Purpose, in the sense of design, teleology, or "Zielstrebigkeit" will probably be found to be quite as sterile a conception as possibility when the biologist succeeds in clarifying the very intricate phenomena which he designates as "adaptations," "coaptations," "regulations" and "restitutions." That the notion of design is often merely a misinterpretation of emergence is suggested by Professor R. B. Perry[30] when he says: "If one speaks of the structure and composition of a whole, as the 'means,' and the peculiar synthetic properties as the 'end,' one naturally supposes that the one 'seeks' the other; or exists and acts 'for the sake of' it; or that the total arrangement has been 'designed'; whereas no such thing is in the least implied." Equally finalistic and reprehensible is the statement, not infrequently encountered even in organicist writings, that the "whole determines the relations of its parts," since this, too, seems to imply—if, indeed, it implies anything—that the end determines the means. The discussion could be greatly prolonged, but perhaps I have sufficiently stressed the inefficacy of theoretical concepts when transferred from higher to lower levels where at best they merely introduce confusion. A very different picture is presented by the theoretical structures that have arisen naturally from the manipulation of the empirical data in any particular science and therefore belong, so to speak, to its own universe of discourse. I allude to such conceptions as the "species," or "taxon" in taxonomy; the "lineage," or "phylon" in phylogenetics; Waagen's "mutations" in paleontol-

[30] *Loco citato*, p. 153.

ogy; "age and area" in biogeography; the "type," or "character" in morphology; the "gene" in genetics; the "reflex-arc" in physiology; the "biocoenose" in ethology; the "abnormal" or "atypical" in pathology; "race" in anthropology; the "complex" in psychology and the "socius" in sociology. Most or all of these are really fictions, or "as-ifs," in Vaihinger's sense, but their practical, heuristic and synthetic usefulness is beyond dispute.[81]

Organicism, conceived as emergence, seems to me to resolve the opposition between historism and naturalism, at least in the forms assumed by these ideas in biology. Emergence can not offend the physiologist, because there is nothing mysterious or unscientific about it. The same is true of the configurationist's formulation of organicism, since configurations, or "Gestalten" occur also among purely physical phenomena, as Koehler has shown. And the radical behaviorists are not only outspoken holists, but adopt a decidedly hostile attitude towards many of the philosophical "residues" in biology, like those I have been considering. On the other hand, the theory of emergence must be welcome to the historistic biologist, because it releases him from the Procrustean bed of mechanism and enables him to express freely the firm conviction which he has always shared with the historians and philosophers, that evolution, both in its progressive and retrogressive manifestations, is a continual generation of novelties, an unceasing process of creation.

The upshot of this rather involved discussion would seem to be that we can clarify and tone down the oppositions among theories by rejecting a lot of adventitious and often mystical notions that have been foisted upon the biological sciences by historians and philosophers, but that certain oppositions will remain for the simple reason that organisms embrace no less than four disparate levels of emergence, the physicochemical, the organismal, the mental and the social. Hence, till the advent of a few Supereinsteins, theoretical biology must stand as a combination of oppositions—a *compositio oppositorum*. This is not a "Zersplitterung," however, as conceived by the critics, presaging decomposition or dissolution, but a sign of vigor and vital unity, like that of the healthy organism, in which what we call life is intrinsically the antagonistic synergy of its component parts. The hopefulness of the present biological situation is even more apparent in the attitude of the creators of the biological theories, the biologists themselves. So impressive is the amount and quality of accomplishment in every one of the biological sciences that not even the narrowest specialist can now adopt the unsympathetic attitude so prevalent among eminent investigators of the past generation, for the veriest tyro soon becomes aware of his indebtedness to his fellow investigators in the most remote biological sciences. Even those tiresome old ladies, the taxonomists, are regarded as rather helpful by petulant infant geneticists, if only as donors of the India-rubber species on which they cut their milk teeth. But there is among biologists a stronger bond than that of mutual gratitude for services received and that is their common love of the living world and their desire to arouse such a love in others. The great museum in which we are meeting is one of the glorious manifestations of that feeling. There is one of Augustine's aphorisms—*res tantum cognoscitur, quantum deligitur*, a thing is understood to the degree that it is loved—which, with some interpretative manipulation, may serve to

81 H. Vaihinger, "Die Philosophie des Als Ob," 9–10 Aufl. Leipzig, 1927. For a discussion of the main fictions in biology see J. Schultz, "Die Grundfiktionen der Biologie," Berlin, 1920.

convey my meaning. Of course, Augustine would have been shocked or perhaps outraged had he deemed it possible that a mere worldly biologist could tamper with one of his most edifying remarks. From the context we may infer that the saint used "diligitur" in the sense of "contemplative or devotional love." I wish to interpret it to mean something like "investigative love." These words, unfortunately, can be construed in the sense of "perverse" or "morbid" curiosity, which might horrify or even infuriate not only Augustine but all the saints in the calendar. I hasten to state, therefore, in conclusion, that I am using the words "investigative love" with a strictly proper meaning and as the best I can find to designate that union of the historistic and naturalistic interests which seems to inspire an ever-increasing number of our biologists and promises the fullest ultimate understanding of animate nature.

MIGRATIONS OF ASIATIC RACES AND CULTURES TO NORTH AMERICA[1]

By Professor FRANZ BOAS
COLUMBIA UNIVERSITY

EVER since we have learned to look at the development of man as a historical process the interest of the student has been directed toward the discovery of our ancestry, of the place of the first appearance of man on our globe and of the history of his migration over the continents. A special aspect of this problem is the history of the appearance of man in America.

All the evidence that we possess up to this time leads us to believe that man did not develop from lower, ancestral forms on the western hemisphere. All his closest relations among the higher mammals live and lived in early geological periods in the Old World; in Europe, Africa and Asia. No forms from which man can be descended have ever been found in America. A single tooth, found in Nebraska, which was once believed to have possibly belonged to a higher ape, has proved to be that of a peccari.

It seems, therefore, reasonable to assume that man developed in the Old World and came to America later. The time of his immigration can not yet be fixed with any degree of certainty, but some limitations may be established. Since the end of the Tertiary the Old World and the New have been separated by the Atlantic Ocean so that the immigration of living beings in this direction has been impossible ever since the land connection in the far north disappeared. If Tertiary man existed in Europe, as is claimed by some investigators, he might have come to America over the old land bridge. We have, however, no evidence whatever of the presence of man in the New World at this period.

Although negative evidence, in this case the lack of finds, is never conclusive, there are other reasons that induce us to conclude that man did not reach America by this route and at this early period. The earliest remains of man found in Europe differ from modern races. They are rather predecessors of modern man, although not necessarily his immediate ancestors. The American race, on the other hand, is morphologically closely allied to the Mongolid race of Asia. Notwithstanding the great differentiation of American Indian types in North America and South America, they bear throughout a decided resemblance to the East Asiatic type and differ from all other races. Even the earliest remains of man found on the western hemisphere share these characteristics. We must, therefore, assume that these two groups had a common origin. The differentiation of the Mongolid race must have occurred before man came to America.

Just when this differentiation developed is still an open question. If it is permissible to judge by analogy, we might place these events in the later Paleolithic period, contemporaneous with the appearance of the Cro-Magnon type. It is, however, quite possible that the origin of this race may date farther back and that it may have appeared in Europe towards the later part of the long Paleolithic period. The determination of the period in which the differentiation of the negroid and Mongolid races occurred will give us the earliest date of the arrival of man in America.

[1] Address before a joint meeting of the American Association for the Advancement of Science and the American Anthropological Association, New York, December 29, 1928.

Positive evidence is still lacking of man's arrival before the end of the great glaciation that separated America from the Old World. Even the most carefully investigated finds that have been made admit of the explanation that they belong to the early post-pleistocene, to a period when the great glaciers had retreated northward. They show, however, that the technical skill of man in the early post-pleistocene was far advanced. The forms are not distinguishable in technical character from those of the modern Indian, before the advent of the Europeans. There is an apparent contradiction between the paleontological evidence and the types of implements found. The animals with which the earliest human remains are associated, are in part extinct and fossilized. Their geological position suggests that these forms may have become extinct much later than is usually assumed.

The final determination of the problem of the first arrival of man on our continent will be solved by geologists. It is a geological problem requiring the determination of the period in which the strata were deposited that contain the remains of animals, of man and of his handiwork. The paleontologist and anthropologist must accept the findings of the geologist and they must shape their conclusions according to the chronology established by the geologist. Unfortunately, this fact is not yet sufficiently recognized and too great weight is given to the types of animal, man and artifacts found. Efforts must be made to ascertain with the greatest accuracy, the geological age. Apparent contradictions between the geological and paleontological or anthropological evidence may lead to a reexamination of the geological conditions, but the decision must be made by the geologist. The closest cooperation between geologists, paleontologists and anthropologists must, therefore, be demanded.

A consideration of the actual conditions on the American continent makes us inclined to consider the post-pleistocene period as rather short for the development of the differentiation in types and languages that has occurred.

If it is true that man came here by way of Siberia and the extreme northwestern part of our continent, at a time when a wide land-bridge existed in place of Bering Sea, and gradually spread over North and South America, he was compelled to become acclimated to the tropics, and in his further migrations southward, to the inhospitable climate of the extreme southern part of South America. The American Indians of various areas differ considerably among themselves and there must have been sufficient time for the development of distinct types. The languages differ enormously in general structure and we must allow time for their development. The fundamental differences in bodily form, language and culture must always be borne in mind and should not be slurred over.

It is not likely that the migration of man into America occurred just once. It may have been a continuous process extending over a long period and bringing different types and different languages into our continent. If we were to assume that the various types and languages represent, unchanged, different waves of migration, we should merely add a new hypothesis to the others, for there is no evidence that the American types existed at an earlier time in Asia.

On account of these considerations it seemed appropriate to consider the whole problem from another angle. Instead of asking what has happened in earliest times, we might rather investigate the relations that exist at present between the two continents and inquire what historical inferences may be drawn from them. It was this problem which I presented in 1896 to Morris K. Jesup, president of the American Museum of Natural History, and which led to the

organization of the Jesup North Pacific Expedition, which was liberally financed by Mr. Jesup and the direction of which was entrusted to me.

The problem before us was primarily an investigation of the coast region of the North Pacific Ocean for the purpose of determining the anthropological interrelation between America and Asia. This necessitated a careful investigation of the anthropological types, languages and cultures of the whole area, together with an attempt to ascertain their development during early times by means of an archeological inquiry.

It was known from previous investigations that the east Asiatic type and the Northwest American type show close resemblance, so much so that in some individuals it might be doubtful to which continental area they belonged; but the local types of the whole district were not well known. It was one of our tasks to obtain a better insight into the relations of native types. In the extreme north we find the Eskimo of Alaska. The eastern Eskimo present a very characteristic and easily recognized bodily form which sets them off sharply from their southern Indian neighbors. In Alaska these features are not so pronounced and relationships appear to both the Indian and East Asiatic forms. Still, the people are most closely related to the Eskimo type. On the other hand the types of the coast of southern Alaska and of the adjoining interior do not seem to me to an equal degree distinct from those of southern Siberia. The similarity of the crania of the two groups has been shown by Dr. Dina Jochelson-Brodsky. They differ, however, in facial form. Later on the observations of Russian investigators were corroborated by Dr. Hrdlička. His claim that the difference in facial form is secondary, due to environmental conditions, can not be claimed to be more than a hypothesis. A comparison of American and Siberian forms is made difficult by the extended migrations that have occurred in Siberia, where Turkish and Tungus tribes have, to a great extent, superseded the ancient native people.

The two outstanding problems are, therefore, the examination of those areas in which those types of the two continents occur that are most alike, and the other one how to interpret the distribution of dissimilar types. So far as we can see at present, the Eskimo and perhaps also the Arctic Siberians separate two types that show a certain degree of similarity. This may be due either to a parallel development or to an older historic relation. Evidently the solution of this question can be given only by a widely extended investigation of the prehistoric remains of this area, an expensive and laborious undertaking that lay outside of the possibilities of the Jesup Expedition. Unfortunately up to this time material from Alaska has been collected more with a view of accumulating masses of objects rather than of obtaining a carefully observed stratigraphically determined series. In recent investigations Jenness and Collins seem to have devoted greater care to strata and sequence. The problem to be decided is, whether the Eskimo type is the oldest one in this area, or whether it is intrusive and overlies more ancient types similar to those of the Northwest coast. By this investigation we may also determine whether the Eskimo intrusion came from the West or from the East. This must remain an open question until careful and extensive observations on the ancient remains of the whole area, extending from the Amur River northward and along both coasts of Bering Sea, will be undertaken. This is at present one of the most urgent needs for the solution of the problem of the interrelation between the early populations of America and Asia.

The relation between Asia and America may also be investigated by an examination of the modern cultural forms.

The work of the Jesup expedition was devoted particularly to this problem.

First of all it seemed necessary to inquire into the possibility of linguistic relationships. Siberia and the Pacific Coast of America belong to those parts of the world in which we still find a great number of apparently unrelated languages, each spoken in a limited area. In Siberia the older conditions have been disturbed by the influx of Tungus and Turkish tribes. According to recent observations by Professor Bogoras, one of the valued members of the Jesup Expedition, many of the small tribes that speak now Turkish dialects must be considered assimilated tribes. What language they may have spoken in early times can not now be ascertained. The isolated tribes of Siberia are generally designated by the term Palaeasiatics, and Professor Bogoras and Mr. Jochelson find their similarity to the American tribes so striking that they speak of them as Americanoid.

On account of the fundamental structural differences of American languages among themselves and similar differences of the Siberian languages among themselves, it is impossible to trace the origin of American languages to Siberia or those of Siberia to America. The eastern Siberian languages have certain features in common with other Asiatic languages, for instance, the importance in their structure of vocalic harmony, while in regard to other traits such as the incorporation of the nominal object in the verbal complex they resemble certain American types.

A comparison between Chukchee, a language of the extreme eastern part of Siberia, and of the Eskimo reveals a peculiar relation. While the fundamental traits of the structure of these languages are quite diverse, a number of peculiar features are common to both. Some of these are purely formative elements, like the suffix *-t* which forms the plural. Others are rather psychological categories that are expressed in both languages, although they are absent among the neighboring tribes. To this group belong the similar development of verbal modes, and the peculiar difference in the treatment of the subject of transitive and intransitive verbs, a feature which occurs in many American languages. I believe we may infer from this ancient cultural contact so close that it has resulted in the contamination of linguistic structure.

More conclusive results have been obtained through a study of other cultural traits of the tribes of this area. A careful analysis has led us to recognize the fundamental unity of the culture of the circumpolar area of both the New and the Old Worlds.

A single problem of unusual interest may be mentioned first. The type of man found in the deposits of the late Magdalenian resembles the modern Eskimo and the implements of that period are not unlike those that characterize the modern Eskimo culture. On this basis the conjecture has been made by Boyd-Dawkins that with the gradual retirement of the Tundra northeastward, Magdalenian man, the so-called Cro-Magnon race, followed the reindeer northeastward and thus travelled through Siberia and finally reached the American continent, so that our Eskimo would have to be considered descendants of the Cro-Magnon race. While we may acknowledge the attractiveness of such a hypothesis, it is hardly acceptable at this moment; not so much because there are important differences between the two human types and the two cultures, for these might have developed in a long span of time, as for the reason that there is no archeological evidence connecting these remote areas. It would be necessary to show that the Cro-Magnon type and his culture left remains in the intervening parts of Asia. The few prehistoric sites in Siberia which have come to our knowledge, particularly through

the efforts of Petri, do not give us any clue that would corroborate the hypothesis. The similarity between Magdalenian and Eskimo is, however, great enough to deserve further study, which must be carried on in Siberia and eastern Europe. The most recent investigation of Eskimo culture over the whole district from Alaska to Davis Strait has proved that the modern Eskimo culture has almost everywhere degenerated from an older type which was technically, and in art forms, far superior to that of the present time. The similarity between Magdalenian and Eskimo must, therefore, be based more rigidly on a comparative study of ancient Eskimo culture rather than on that of modern times.

The characteristics of the circumpolar culture are only in part explained by the similarity of geographical environment. The climate does not permit agriculture and all the people rely essentially upon animal food, fish, sea mammals and land animals. The domestication of the dog is known not only to the circumpolar region but is well-nigh universal. It is, howêver, characteristic of this region alone that the dog is used as a draft animal. It is not unlikely that the dog cart which has been used up to the present in northern Europe is a survival of this use of the dog. In Asia and Arctic America the dog is used as a draft animal in connection with a sledge. In America its use has spread southward from the Arctic region, but the Indian tribes of the Plains use it in a peculiar manner. Instead of the sledge or toboggan, they use a frame resting on two poles which are tied to each side of the dog and which are dragged over the ground. This contrivance, the so-called travois, was used both in summer and winter.

Another characteristic trait of the circumpolar region is the use of birchbark for making vessels and canoes and for building houses. The Indian birchbark wigwam is well known. The construction of the Siberian tent is, in principle, the same. A frame-work of poles is erected and covered over with sheets of birchbark. The bark canoes are also of similar structure.

The possibility of navigation was presumably discovered by the observation of floating logs, floating grass, and by the buoyancy of vessels. We do not know the sequence of the inventions which led to the art of navigation, but it seems plausible that rafts were among the forms first used. In neolithic times in Europe, dugouts were made. Sometimes these were strengthened by ribs left standing when the trunk was hollowed out. It would seem that this invention was easier than that of the canoe consisting of a framework of ribs covered with birchbark or hide, a much more complex structure. In northern Denmark golden votive offerings were found that seem to represent a framework of ribs covered with skins. Caesar described boats of the same kind, as used by the natives of England. Even at the present time the coracle is used in Wales. Boats of this type of structure, covered in the southern regions with bark, in those parts of the country where wood is not available with skins, are characteristic of the whole circumpolar area. In some regions striking similarities are found, thus the general structure of the birchbark canoe of the Amur River and that of the Kutenai of British Columbia are very much alike.

It might be said that the use of skins and bark for covering framework is dictated by the availability of these materials, but this point of view is hardly tenable when we consider also the similarity of the birchbark vessels which are used on both continents. Baskets and vessels of various kinds are formed by cutting and folding birchbark in appropriate ways and many of the ideas of treatment are practically identical. The strengthening of the rim, and the decoration of the sides are characteristic for

Siberia and for America, but they do not seem to occur in other parts of the world.

Attention may also be called to the similarity in the construction of the houses. Particularly in northeastern Siberia and among the Eskimos we find a subterranean house. A shallow pit is dug and a roof erected over it with a smoke hole in the center, which at the same time serves as an entrance to the house, a ladder being placed on the floor and leading up to the smoke hole. In some cases the entrance is through a tunnel at the side. This very characteristic structure has been observed, not only in the Arctic area where it might be explained by the necessity of the climate, but it has also been found much farther to the south. All through the northern part of the great plateaus of the American west we find subterranean houses of this structure. They occur in California and may even be recognized in the underground ceremonial houses of the Pueblos, and in their ancient dwelling houses with entrance through the roof. Farther south in Asia and also on the Pacific Coast of British Columbia, this type of house is not found, but it is remarkable that in mythological tales and in certain sacred ceremonies, the entrance to the wooden houses of these areas is not through a door. The supernatural beings or novices disappear and reappear through the smoke hole. This leads us to think that perhaps in earlier times similar dwellings, with entrance through the roof, may have existed here.

Common to Siberia and America is also the characteristic flat drum, consisting of a hoop covered by a single head, sometimes with a handle consisting of crossed thongs or wire or similar material. In practically all other regions where drums with a single head occur, the shell is high, as for instance in the large drums of Africa. The only other form similar to the American and Siberian drum is the tambourine, which seems to be confined to the Mediterranean and to southern Asia. The tambourine is much smaller and is characterized by the additional jingles.

I do not feel convinced that the use of tailored fur clothing and the methods of fishing can be added as a proof of ancient, historical relationship, because they are so much dependent upon climatic and geographic conditions.

Another feature common to the northwestern part of America and to Asia is the use of slat armor, consisting of cuirasses and other protective devices made of rods or slats, of wood, bone or ivory, securely lashed together. If this type of armor should have developed from Chinese and Japanese patterns it would be proof of an early, long-continued cultural influence that extended northward and southeastward. Of similar character is the use of the sinew-backed bow which is widely used in the Old World and occurs in an extensive area of Northwest America.

Similarities in religious ceremonials, beliefs and traditions prove an intimate relation between Asia and America. Quite recently Dr. Hallowell has published a detailed study of the bear ceremonial in the Old and New Worlds and proved its wide distribution over the whole extent of the circumpolar area and the adjoining districts farther to the south. It is hardly admissible to assume that the cult of the bear has developed independently all over this country on account of the fear inspired by this animal, for form and content are too much alike. At the same time these particular ceremonials are not found in regard to other dangerous animals.

Attention might also be called to the peculiar use of wood-shavings, grasses, and shredded bark as religious symbols which characterize the ceremonials of the Ainu, Koryak, Chukchee, and of the coast tribes of British Columbia and southern Alaska.

Strong proof of cultural relations between Asia and America is found in the folk tradition of the various tribes. In this field the isolation of the Eskimo is

particularly striking. In contrast to most other tribes the Eskimo tradtiion deals much more with human society than with animals, and their more important animal tales can be proved to be of Indian origin. But at the same time the Eskimo are exceedingly tenacious in form and content of their tradition. The same formulas occur in tales from East Greenland and in those from both sides of Bering Strait. The striking differences between Eskimo lore and that of their Indian and Asiatic neighbors, is one of the arguments that speak for a late intrusion of the Eskimo into Alaska. Mr. Jochelson and Professor Bogoras have made detailed comparisons of American Indian and Siberian folklore and they have proved that many elements are common to both. The number of correspondences is so large that independent origin is excluded. If we should judge by the elaboration of the various themes, we might conclude that they have their home in America and were carried to Asia, but such an argument is of doubtful validity, because tales may have degenerated in one area while there may have been a prolific development in another.

A number of themes prove clearly the importation of Old World lore into America. One of the striking examples is the famous story of the magic flight, which is spread in the Old World from Morocco to Bering Strait, and it is known in closely allied form in America all along the Arctic coasts, on the north Pacific Coast, and inland as far as the Mississippi Valley. This tale has been embodied in the most sacred traditions of British Columbia and for this reason it may be assumed that it has been known there for a long time.

Mr. Jochelson has made a statistical study of the episodes of Koryak folklore in comparison with those of the Old World and of America, and he has found that among 122 episodes, 84 per cent. are common to Asia and America excluding the Eskimo; 24 per cent. to Asia and the Eskimo; and that only 20 per cent. are repeated in other parts of the Old World.

The intimate relationship of North Asiatic and Northwestern American culture has been fully established by these researches. A study of American material has also shown that the cultural traits that may be traced to the Old World, extend in America south and eastward to the western plains and the Mississippi Valley, weakening the farther away we move from the Arctic and from Alaska.

Cultural relations of the kind here discussed do not develop suddenly, but are the result of long-continued contact.

In order to understand the relations between America and Asia clearly it is also necessary to investigate the fundamental differences between Siberian and American culture, differences that might indicate a lack of mutual influences.

The fundamental traits of American culture are so distinct from those of the Old World that they corroborate our view of a very early immigration of man into our continent. American agriculture is based on the cultivation of American plants; Indian corn, squashes and beans are native American plants and there is no trace of the use of any of the Old World plants. The Americans had no domesticated animals excepting the dog which had an almost universal distribution, the llama in the Andean highlands and the turkey.

There are also striking differences in the general character of political organization and religious belief. Weakness of administrative function, almost complete absence of judicial procedure characterize American political organization. Absence of a belief in obsession and a different attitude towards shamanism may be observed. Among the American Indians shamanistic power is generally sought, rather than involuntarily imposed. Among the tribes of Siberia it is an unwelcome gift of supernatural power that is resisted.

One of the most striking features is the absence of domesticated reindeer in America while they are used by all the Siberian tribes. For many centuries the Alaskan Eskimo must have been familiar with the domesticated reindeer, still they have never been inclined to take up its domestication. It may well be that the extensive use of the dog was a hindrance, for it requires special training to teach the dogs not to attack the reindeer. The failure to adopt reindeer breeding may also be due to the wealth of sea-life which, under normal conditions, gave to the Eskimo ample supplies with less arduous work than that required for reindeer breeding. The general conditions of reindeer breeding indicate that the art of domestication is least developed among the Chukchee and it seems plausible that the art sprang up in western Siberia and gradually reached the most eastern part of Asia. There is every probability that the tribes of Siberia were by origin hunters and fishermen and that particularly the Chukchee participated in this mode of life. As a matter of fact a large portion of the Chukchee have no reindeer even at the present time, but live as maritime hunters in permanent villages. It is also well worth remarking that the clumsy tent of the nomadic Chukchee is, in its general plan, analogous to the underground house of the maritime Chukchee, so that survivals of older sea hunting life may be recognized even now among this tribe.

It is necessary to look at the whole problem from another angle. The study of American inventions, customs and beliefs shows that a gap exists between the cultures of the central parts of both Americas and the extreme northwest and the extreme south of South America. The advanced civilizations of Central America and of the Andean Plateaus have influenced the greater part of our continent directly and indirectly, and the inventions, customs and beliefs of the more primitive tribes have been overlaid by cultural traits which have spread northward and southward from Central America. The older forms of American culture survive in the marginal areas on the northwest coast and independent development has occurred into which all the tribes that migrated from the interior to the coast have been drawn. The greater part of the continent is, therefore, influenced by a high culture which has developed independently of the Old World and it is, therefore, but natural that closer relations between the two continents will be found in the northwestern part, which is not only nearest to Asia but where also the older traits have not been obscured.

A last problem remains to be solved. If we acknowledge that cultural relations exist between Asia and America, the question should be answered whether the origin of these customs must necessarily be looked for in the Old World. I doubt whether it will be possible to give a categorical answer to this problem, but I incline to the opinion that the general history may have been the following. At an early time the Mongolid races migrated in a number of waves into the American continent and were gradually driven southward by the inclemency of the Arctic climate. Later on when the climate became more temperate, man settled again in the more northern districts and an eastern and western wave turned northward. The outposts of the eastern wave may have been the Eskimo, while the western wave moved across Bering Strait and back into Siberia where they later on amalgamated with Old World tribes which also migrated northward when Siberia became habitable.

We are still far from being able to give a categorical answer to these problems but we may hope that continued researches, and particularly archeological researches, in the Arctic may enable us to clear up the later phases of the migrations of the aborigines.

HEREDITY AND NATURAL RESISTANCE TO DISEASE[1]

By W. V. LAMBERT

IOWA STATE COLLEGE

An animal's development and reaction to various influences throughout its life are governed by two forces, its constitutional or inherited capacities and its environment. Neither force is independent of the other, and to reach the highest plane of development or usefulness an animal must not only be surrounded by a fit environment but it must also be equipped with a good heredity.

In relation to disease the item of constitutional fitness has been largely overlooked. Previous to Pasteur's discovery of the rôle of microorganisms as the causative agents of many diseases this concept was quite generally recognized as an important one by the medical fraternity. Following his discovery, however, the idea was pretty generally forgotten in the mad rush to discover the causative agents of each disease and in developing methods for suppressing and combating them, such as the production of vaccines and immune sera. And in many cases, as typhoid fever, rabies and swine cholera, the results have been remarkable.

In many diseases, however, no successful methods of control have been developed. This fact has led a number of workers, in genetics primarily, to undertake another possible solution of the problem, namely the production of disease-resistant strains. In the plant kingdom this method has been used extensively. As examples, strains of wheat and oats now exist that are resistant to certain forms of rust and smut, beans that are resistant to the fungus disease, anthracnose, are now grown commercially, and in cabbage selections resistant to yellows are in use.

In animals much empirical evidence exists relating to this subject. It has long been recognized that much variation in resistance to bacterial diseases exists in any group of animals. In an epidemic many individuals develop an acute form of the disease, others a mild form, while still others resist it entirely. Some of this difference undoubtedly is due to environment, but not all, for under the same environment and with equally good physical fitness the same facts are observed.

Species, racial and familial differences in resistance to disease are well known. For instance, diseases common to the rat are non-pathogenic for mice, and Texas fever, a common and fatal disease for domestic cattle in tropical and subtropical countries, is not pathogenic for the zebu. Another instance frequently cited is the high degree of immunity exhibited toward anthrax by the Algerian sheep, a disease very fatal for other breeds. In man, also, racial differences have been freely observed. It is a well-known fact that when diseases common to civilized races are introduced into uncivilized or isolated regions, where these diseases have not been present, the mortality resulting among such people is often appalling. The death rate among the American Indians following the introduction of smallpox and measles is a well-known example of this. Much other evidence of a less clear-cut nature also exists. It

[1] Paper No. 26 from the Department of Genetics, Iowa State College.

is generally considered that the negro is more susceptible to tuberculosis than the white man. Much evidence, largely statistical in nature, has been presented to show that susceptibility to tuberculosis is an inherited trait. Its incidence is significantly greater in certain families so as to leave no doubt that a weakness or inherent susceptibility toward this diathesis is an integral part of the germplasm of those families. It must be emphasized here that it is not the disease itself that is inherited, but that there is some constitutional weakness which is inherited that makes certain individuals more prone than others to infection with the tubercular bacillus.

Experimental evidence for the inheritance of resistance to disease in the laboratory mammals is not abundant. While numerous observations concerning the great variability in resistance to disease are on record, few critical attempts have been made to determine how much of this variability was due to environment and how much was inherent within the individual. Within the last few years, however, experimental results have definitely shown that it is possible by selection to produce strains of animals having a higher degree of resistance to infection with a specific bacterial disease than that possessed by the general population. This has been demonstrated in several species and for such diverse diseases as mouse typhoid, bacillary white diarrhea in chickens, fowl typhoid and for a disease among rats induced by inoculation. It has, likewise, been demonstrated that inbred lines exhibit markedly different reactions when subjected to certain of the infectious diseases. This latter point bears directly on the problem, for inbreeding as a system produces pure or homozygous types. Hence the demonstration of such differences between inbred lines points conclusively to the fact that it is possible to concentrate factors for resistance or susceptibility to a given disease within certain strains.

From an evolutionary standpoint the latter fact has great theoretical interest. It is more pertinent in plants in some of which self-fertilization, the closest form of inbreeding, is the natural method of reproduction. It is within such highly inbred forms that naturally resistant lines of plants have been found to exist. During the evolutionary history of these plants it is probable that most of the diseases now common to them have been present for centuries. General outbreaks of these diseases have occurred from time to time and during such an outbreak only those plants possessing a natural resistance have survived. Such plants through self-fertilization have been from generation to generation the parent plants of the strains now existing. With inbreeding tending to produce homozygous types and with nature eliminating those types that were not pure or reasonably pure for resistance, the result has been the gradual evolution of races or strains pure for resistance to a given disease. In those instances in which resistance was dependent upon only a few factors such strains were undoubtedly produced in a few generations, whereas if resistance depended upon many factors the production of such strains was very likely a much longer process. The speed of production of resistant lines was also probably affected by the frequency and severity of the infections. For instance, if infection occurred every year in a severe form the production of such types would be relatively a quick process. If, however, as is more probably the case, severe outbreaks of the disease were rather infrequent due to lack of favorable environment, the production of resistant strains would be proportionally slower.

In the higher animals crossbreeding is the normal method of reproduction, and

such a method permits the impure or heterozygous types to remain about the same from generation to generation. As a result homozygous types have not been produced and accordingly this method of reproduction undoubtedly has accounted for the lack of disease-resistant types of animals. For centuries nature has been selecting each generation only those individuals equipped with the proper inheritance to withstand disease, but unfortunately such individuals have generally been impure or heterozygous for the resistant factors. Because outbreeding perpetuates these heterozygous types, resistant lines of animals have not been evolved, and the race has tended to revert to a generally heterozygous condition. Conceivably, if the disease had occurred every year in very severe form entirely resistant races might have been produced, but such was not likely the case. That such a tendency has been apparent, however, is shown by the aforementioned fact that uncivilized or isolated races are much more susceptible to diseases of the civilized races than are the people of a region in which those diseases have been prevalent for centuries.

If nature has been able to evolve completely resistant lines in naturally inbred species, and has shown a tendency toward producing partially resistant lines in outbred species, it is reasonable to believe that by rigid selection based upon an animal's ability to produce resistant offspring, the use of a moderate amount of inbreeding and with constant exposure to a virulent type of the disease, naturally resistant strains of animals may be produced. With these reasons in mind the problem of producing a strain of chickens having a sufficiently high natural resistance to withstand general epidemics of fowl typhoid was undertaken in the writer's laboratory. While the ultimate goal is far from achievement, some facts of general interest have accumulated.

As foundation material healthy mature chickens were selected and each bird was fed the same quantity of a virulent culture of fowl-typhoid bacteria. From the survivors of this group those birds that had shown the least reaction to the disease were selected and used as breeding stock. The next year the chicks from these birds were infected with a standard dose of the fowl-typhoid bacteria, a dose that in preliminary tests had been found to be lethal for approximately 90 per cent. of all chicks secured from ordinary outside sources. Concurrently with the infection of the chicks from the surviving parents an approximately equal number of chicks with similar breeding but from an outside source were also infected. The chicks from the surviving parents showed a total mortality of 41 per cent., whereas those chicks that came from non-surviving parents gave a total mortality of nearly 90 per cent. This is a difference in mortality between the two groups of nearly 50 per cent., a difference that certainly can not have been due to chance alone, since over eight hundred chicks were used.

Thinking, perhaps, that a large part of this difference in resistance between the above groups of chicks might be transmitted in some manner through the yolk of the eggs of the surviving mothers, typhoid-surviving males were mated to hens of similar breeding that had not been exposed to fowl typhoid. The total mortality observed in the chicks of these matings was approximately 60 per cent., a figure intermediate between that of the first two groups. In this case the increased resistance of the chicks came from the sires alone, and since numerous experiments have indicated that passive immunity cannot be transferred from the male to his offspring, the resistance must have been due to factors for resistance resident in the germ cells of the sire. The reciprocal cross, namely typhoid-surviving

females × non-tested males, gave approximately the same results.

Not only in total mortality, however, was there a difference in the three groups of chicks. The rate or speed of mortality exhibited the same general relationship. The chicks with double typhoid-surviving ancestry showed a slow rate of mortality; those with single typhoid-surviving ancestry, an intermediate rate; and the group with non-typhoid ancestry, a very rapid rate. This indicates a higher potential of resistance in those chicks whose parents had both withstood an attack of the disease, although, as indicated by total mortality, this potential was not high enough to protect all chicks against death from the infection.

It has been found, also, that sires differ markedly in their ability to transmit resistance to their progeny, a situation that would be expected if resistance to this disease were an inherited character depending upon a number of factors for its expression. These differences were so marked in some cases that there can be no question of their significance.

The findings reported herein have been accumulated over a period of three years and the relationships from year to year have been very consistent. This consistency indicates clearly that the hereditary basis for resistance is reasonably constant in any given strain of chickens. It has also shown that the experimental technique is sufficiently accurate to enable us to predict within fairly close limits what may be expected in any given trial.

Another experiment dealing with the same general problem has been carried on in this laboratory, using the rat as the experimental animal. It has been proven beyond question that selection is effective in producing inbred lines of rats having a much greater resistance to the Danysz bacillus than that existing in an unselected population. Furthermore it has been shown that the second selected generation has a much higher degree of resistance than the first selected generation. Crosses between susceptible and resistant strains have also demonstrated that there is a genetic basis for resistance to disease that is transmitted through both the female and male rat. However, the immediate problem now is to develop by selection a strain of rats more highly resistant than any at present existent.

This demonstration of the possibility of selection is the main contribution of these experiments to date. Whether selection based upon the above basis will result in the eventual development of naturally disease-resistant animals remains to be seen. The possibility has been clearly indicated but many unforeseen difficulties may be ahead of its ultimate accomplishment. If accomplished, the value of such experiments will be untold. Chiefly, perhaps, from the practical standpoint, but not alone, for many problems in immunology and bacteriology may be solved only when hosts that can be depended upon to react in a constant and definite manner toward certain microorganisms become available. And lastly if they should help in an eventual revival of the idea of constitutional fitness as one of the sound policies of eugenics they may result in vast benefits for mankind in ages to come.

CHILDREN OF THE SUN

By Professor JOHN HODGDON BRADLEY, Jr.
UNIVERSITY OF MONTANA

A SEA whose shores no eyes have ever seen, whose depth no instrument can fathom, whose waters no scientist can analyze—such is the sea of space. Nothing can be as empty and cold as the gulf wherein our destinies are immersed. Star worlds, like fish in schools, drift through the void, star worlds as large as our sun and many times larger, in schools of hundreds of millions. Unlike a school of fish, whose direction may be changed by a whim of the leader, whose organization may be destroyed by the rush of an enemy, whose fate is in the hands of a shifty environment, the stars in their galaxy move with the majesty of perfect orderliness. From the smallest satellite slave of the smallest star to the largest super-galaxy of worlds in space, everything bows to the first law of nature. Chaos and caprice do not exist.

Hundreds of millions of stars are visible to the powerful eyes of astronomy. They are grouped in the shape of a thin watch whose greatest diameter is ten to fifteen times the thickness. Light consumes perhaps as much as one hundred thousand years in traveling along the equator of the disk, light which moves at the speed of more than 186,200 miles in a second and can circle the earth seven times during one beat of the human pulse. The Milky Way, where the stars seem more thickly grouped, reveals our position in the galaxy. We are near the outer edge, and when we see the clotted light of the Milky Way, we are looking through the long diameter of our universe. Many kinds of stars are brothers of our sun, stars of incandescent gas, dark dead stars burned to cinders, single and multiple stars in open and closed clusters, stars in vast irregular clouds, as well as much nebulous fire-mist of uncertain character. Everything is in motion, not only the galaxy as a whole, but all the minor states in the republic of suns.

Our own sun, with its coterie of devoted attendants, wends its way through the swarm, held by the mysterious power that keeps the worlds in our universe together and pulls them ever into more intimate association. Copernicus violated the vanity of men when he proved the earth a mere satellite of the sun. Modern astronomy goes further and paralyzes the imagination. Our sun is but one among hundreds of millions. And the hordes of visibly blazing suns are probably not all. Dead stars, like dead men, may be more numerous than live ones. Outside our galaxy are other universes, similar to our own in shape and size, so distant that their light reaches us only after a million years.

Like jetsam in an ocean current, the sun and her small family voyage through space and time, with man a microbe on a drifting fragment, a molecule in an infinity, a moment in an endless day, lost in the cosmos, his purpose as obscure as his destination. Fortunately for his peace of mind, man's philosophy does not often rise to astronomical heights. The largest star in the firmament might disappear for all he cares. His concerns are down on earth with his problems. Yet he may well take some interest in the universe without. From a catastrophe in this universe his life began, and from a similar catastrophe it may some day end.

No modern scientist doubts that all the planets, moons, asteroids, meteors and comets in our solar system were born of the sun. The blood relationship of earth and sun has been proved by the spectroscope. This instrument breaks up the white light of the sun into a series of colors. Each color denotes the presence of a definite chemical element. The composition of the sun is thus known to be very similar to that of the earth. More than forty elements known upon earth are present in the sun. The other planets and their moons, the meteorites and the comets show no elements foreign to earth. The kinship of all members of the solar system is a clear fact.

The birth of the earth and her sister planets has inspired several guesses. For many years the views of the French astronomer, Laplace, were accepted. He thought the parent sun a nebula of hot gas with a diameter of more than five billion miles, sufficient to include the orbit of the outermost planet, Neptune. This mother nebula rotated slowly, shrinking and gaining speed as it cooled. A ring of gas was eventually detached, which condensed into a gaseous spheroid, rotating about the sun. Thus was the first child, the planet, Neptune, born. Again and again rings were thrown off the contracting sun, and Uranus, Saturn, Jupiter, Mars, Earth, Venus and Mercury in turn took up a separate existence. In similar fashion the planets gave off rings that collapsed into moons, rotating about the planets as the planets rotate about the sun.

But alas for theories that germinate in the minds of men! They wilt in the bright light of advancing knowledge. To-day any college freshman can know what Laplace could not have known, that in the evolution of a gaseous nebula, the high activity of the molecules would have scattered the materials of the rings in space before the rings could form; that even if the rings had formed, they could not have condensed into a spheroid. The lighter gases of the earth's atmosphere would have rushed into space, overcoming gravity with the indomitable energy of their molecules. Furthermore, the gas in the earth ring would doubtless have cooled to a solid long before the time when the gaseous moon ring was thought to have formed.

The nebular hypothesis has other failings. It is too simple to explain the complexities of movement in the solar system. There is much doubt that the mother nebula could have detached a ring before it had shrunk well within the orbit of Mercury, the innermost planet. If the views of Laplace were true, the satellites should revolve in the direction of the rotation of their planets. But one moon of Saturn and two moons of Jupiter revolve in the opposite direction. The planets should be rotating faster than their moons, and the sun fastest of all, because with cooling and contraction the speed of rotation should have increased. Yet Phobos, the inner satellite of Mars, circles its planet three times while the planet turns on its axis but once. Jupiter, with less than one thousandth of the mass of the solar system, has most of the movement, movement which according to the theory should be invested in the sun.

Thus it is that the nebular hypothesis must blush before the facts of modern physics and astronomy. But youthful sciences grow vigorously and old tissues of theory are replaced by new. The nebular hypothesis will take its place in the history of sciences as a boon to progress through its very errors. For men must have a cosmogony, and false cosmogonies, like false gods, drive the thoughtful to search for the ultimate truth.

Perhaps the greatest contribution to theoretical science since the Darwinian renaissance in biology was the planetesimal hypothesis of Professors Chamberlin and Moulton, of the University of

Chicago. Like the savants before them, they believe the earth an offspring of the sun, but unlike Laplace, they allow her not only a mother but also a father. A star is thought to have passed near enough the ancestral sun to exert a gravitative pull. Even now the sun is belching incandescent materials from its surface almost three hundred thousand miles into space and at the rate of more than three hundred miles a second. Normally these materials fall back into the sun. But at the time when the solar system was destined to come into being, great arms of this eruptive stuff are thought to have been forced from either side of the sun and bent into spirals by the attracting force of the visiting star as it passed by. The sun was not strong enough to pull back its substance after the star had moved on, so that the ejected matter in the spiral arms remained detached. In the cold of space this gaseous material quickly froze to solid bodies that took the form of knots, some large and some small, with many finer particles between. All bodies thus formed revolved in elliptical orbits about the sun.

In time the large knots in the spiral arms collided with the smaller particles because of the eccentricities of the elliptical orbits. Slowly the large knots grew larger, absorbing by means of their superior gravity the lesser material in their paths. Each knot was the forerunner of a planet, and grew by sweeping up the smaller planetesimals. The satellites, growing in the same way, never became as large as the planets because they were smaller at the start. With every collision the planetary orbits were modified from the elliptical toward the circular. It is a striking fact that the largest planets, Jupiter, Saturn, Uranus and Neptune, which are supposed to have absorbed the greatest amounts of planetesimal material, have nearly circular orbits, whereas the insignificant planetoids, by-products of the solar system, move about the sun in highly eccentric pathways. Variation in the manner and rate of infall of the planetesimals accounts for the fact that some planets spin slowly and others rapidly, and that three satellites move in a retrograde direction.

The planetesimal hypothesis is the best cosmogony modern science can offer because it best explains the known facts of the solar system. But modifications of certain details have been argued. Barrell maintained that planetesimals of considerable size must have fallen upon the solid earth nucleus with force and rapidity enough to melt the growing planet. Jeans and Jeffries believe that the planets and their satellites were gaseous and liquid from the beginning. The advocates of the planetesimal hypothesis insist that the earth grew slowly, predominantly cold and solid throughout its history.

Unfortunately, vital facts necessary to prove any of these assumptions are buried beneath the accumulated rock debris of later eras. If the earth had condensed from a liquid, we might expect to find remnants of the original crust that formed over the cooling globe, like slag in a blast furnace. Nowhere has the prying eye of science made such a discovery. If the earth had been built slowly from cold planetesimals, we might expect to find traces of such material. But nature yields no easy victories; change has obscured or destroyed the record. With our present knowledge we can know but one thing with certainty, that the earth could not have been both liquid and solid at the same time. In a wilderness of speculation the path to truth is hard to find. Yet time and its revelations may some day point the way.

For the present we must be content with two stories about the early history of our planet. One or the other may eventually be proved true, but it is not

impossible that both are false. Those who believe the earth solid from birth see it first as a knot of solid material about one tenth the present size. Slowly this nucleus gathered to itself the star-dust in its path. The infalling planetesimals were not large enough to liquify the earth, but the heat of their impact liberated some gas. As the globe grew larger its gravity was able to prevent the escape of part of this gas. The blanket of the atmosphere began to form. At the same time, decay of radioactive minerals generated heat, internal pressure in the growing earth increased and developed more heat, easily fusible rocks were changed to liquid in pockets, volcanoes were born, more gas was given to the atmosphere. The water vapor in the young air was multiplied until some of it condensed as rain. Pools of water stood on the earth's rocky surface. Low areas were eventually filled with water and the oceans began their long careers.

Life came as a natural result of favorable conditions. Its past has been a long struggle toward perfection. Its future may be glorious beyond even the dreams of the past. For life will go struggling on as long as it is allowed to exist, and the end of present conditions is lost in the future.

Those who believe in a formerly liquid earth tell a sadder tale, of an earth that yesterday was steaming under the white heat of Hades, and to-morrow will be as cold and dead as the moon. The whole solar system is running down. Life is but lightning flashing in a troubled night, destined to vanish with the day. We now enjoy the special conditions necessary to our existence, enough air and water, temperature of the correct range. But the earth is stiffening in death. It will freeze to the absolute zero of space. Man and all his lower relatives will breathe no more. The sun and her children will continue to swing through space and time, the past but a memory of glory lost, the future devoid of hope.

At present we can not know, but time may yield the truth. Meanwhile lovers will go on with their love, politicians with their wars, and scientists with their theories.

THE AUTOCHTHONAL TALE OF JACK THE GIANT KILLER

By HARRY B. WEISS

NEW BRUNSWICK, N. J.

In spite of Cotton Mather's exemplary "Elizabeth Butcher" who, when she was two and a half years old, asked herself, "What is my corrupt Nature?" and answered herself, "It is empty of Grace, bent unto Sin, and that continually," and in spite of her practice, when she was six years old, of carrying "her Catechism or some other good Book to Bed with her," and getting up early the next morning to read it—in spite of the example set by this pious little lady of Boston, New England must have harbored a number of depraved little wretches who gave no heed to their corrupt natures and who took to bed with them, not catechisms, but copies of "The Pleasant and Delightful History of Jack and the Giants." And who could blame them when the title page promised "A full Account of his Victorious Conquests over the North Country Giants; destroying the inchanted Castle kept by Galligantus; dispers'd the fiery Griffins; put the Conjuror to Flight; and released not only many Knights and Ladies, but likewise a Duke's Daughter, to whom he was honourably married." Giants, fiery griffins, conjurors, castles, knights and ladies—direct from Nottingham, Newcastle, Banbury and London—with pictures of Jack strangling the giants, playing tricks and otherwise performing strictly as advertised on the title page—all for one penny.

Although it may seem incredible, there are actually some people so old that they either have forgotten the adventures of Jack the Giant Killer, or have him hopelessly confused with Jack and the Bean Stalk, and so for the purpose of setting these unfortunates straight, it may be well to review, briefly, the "pleasant and delightful history of Jack and the giants."

Jack, the son of a wealthy farmer, flourished during King Arthur's time, in England, which country suffered from the thieving propensities of a race of dumb but troublesome giants. His first adventure consisted in outwitting the giant Cormoran, of Mount Cornwall, by digging a pit, into which Cormoran fell, and then neatly dispatching him by a blow on the head from a pick-axe. The news of this outrage reached the giant Blunderboar, who lived in an enchanted castle in Wales, and Jack was unfortunate enough to fall into Blunderboar's hands. He was locked in a room of the castle while Blunderboar hunted up his brother so that both could enjoy the killing. However, Jack found two strong cords in his room, and while the giants were unlocking the gate, he managed to get running nooses over their heads and of course they died of strangulation. Next, a Welsh giant, with two heads, who appeared friendly, invited Jack to a room in his house, and Jack would surely have lost his life in the night had he not substituted a billet of wood for himself, in bed, which billet the giant struck with a great knotty club. The next morning at breakfast, Jack, instead of eating four gallons of hasty pudding, managed to slip it into a leather bag under his coat, then telling the giant he would show him a trick,

he ripped the bag open and the pudding plopped out. The giant, wishing to imitate such a delightful trick, ripped open his own *scrobiculus cordis,* his "tripes and trullibubs" fell out and that was the end of him.

Jack then met King Arthur's son and both of them visited a three-headed giant who had a tremendous reputation as a fighter. Jack, however, so scared this giant by telling him that the King's son with a thousand men was on his way to kill him, that the giant begged Jack to lock him up in a vault until the prince had departed. This Jack did and the grateful giant presented him with a coat which would make the wearer invisible, a pair of shoes of incredible swiftness, a cap of knowledge and a sword which cut asunder whatever it struck. With this magic equipment, Jack outwits the evil spirits who had enchanted a beautiful lady, thereby making it possible for the prince to wed her. All then return to the court of King Arthur, where Jack is received with acclaim and made one of the Knights of the Round Table.

Jack then adopted giant-killing as a vocation, and after being supplied with money and a horse, he started out to rid the realm of "cruel and devouring monsters." Against his magic trappings the giants did not have the ghost of a chance. He cut off giants' legs, noses and heads, rescued worthy knights and fair ladies, distributed treasures, outwitted the two-headed Thunderful, author of "Fe, Fi, Fo, Fum," etc., and sent his heads to King Arthur. But his crowning achievement was the slaughter of Galligantus, who collaborated with a conjurer in transforming knights and ladies, including a duke's daughter, into "sundry shapes." Jack passed the fiery griffins, wearing his invisible coat, and having reached the gate of the castle he blew a golden trumpet which hung there. This caused the castle to tremble, and just as Galligantus stooped to pick up his club, Jack decapitated him with his sword of sharpness. The conjurer was carried off by a whirlwind, the castle vanished and the knights and ladies assumed their proper forms. Upon their return to the Court of King Arthur, Jack married the duke's daughter and lived happily ever after in "a noble house, with a large estate."

This brief and inadequate summary does not, of course, give one any idea of Jack's cunning over the stupid giants, of his ready wit, of his entertaining conversations with the giants, of how he liberated fair ladies, of how the giants ate men's hearts and livers with pepper and vinegar, of the dreadful shrieks which emanated from knights and ladies being held by the hair of their heads, of the terrible appearance of some of the giants, with eyes of fire and cheeks like sides of bacon; for these, one must consult a version which has not been softened by the Society for the Supervision of Children's Reading, or whoever it is that does such things.

The oldest edition of this nursery tale appears to be one dated 1711, supposedly in the British Museum, entitled "The History of Jack and the Giants" (12mo. n.d.). "The Second Part of Jack and the Giants, giving a full account of his victorious Conquests over the North Country Giants, destroying the Enchanted Castle kept by Galligantus, dispers'd the Fiery Griffins, put the Conjuror to flight, and released not only many Knights and Ladies, but likewise a Duke's Daughter, to whom he was honourably married." (12mo. Newcastle, 1711.) This edition is illustrated by rude woodcuts, representing the important events of the history. The tale was current, however, long before 1711. In "King Lear" (c. 1605) Edgar as Mad Tom says:

> Child Rowland to the dark tower came;
> His words were still "Fee, fow and fum!
> I smell the blood of a British man."

And in "Have with you to Saffron Walden," 1596, by Nash, there is mentioned "a precious apothegmaticall pedant who will finde matter inough to dilate a whole daye of the first invention of

> Fy, fa, fum,
> I smell the bloud of an Englishman!"

Sir Francis Palgrave believed that Jack the Giant Killer was one of the popular stories founded upon King Arthur and his adventures, although certain features of the latter are to be found in popular Asiatic tales. In Malory's "Morte d'Arthur" (1485), Arthur's fight with the giant of St. Michael's Mount is told in frightful detail.

> Thenne the gloton anone starte vp and tooke a grete clubbe in his hand / and smote at the kynge that his coronal fylle to the erthe / and the kynge hytte hym ageyn that he carf his bely and cutte of his genytours / that his guttes and his entraylles fylle doune to the ground / thenne the gyaunt threwe awey his clubbe / and caught the kynge in his armes that he crusshyd his rybbes / Thenne the thre maydens knelyd doune and callyd to Cryst for helpe and comforte of Arthur / And thenne Arthur weltred and wrong / that he was other whyle vnder and another tyme above / And so weltryng and walowynge they rolled doune the hylle / tyl they came to the see mark / and ever as they soo weltred / Arthur smote hym with his daggar / and it fortuned they came to the place / where as the two knyghtes were and kepte Arthur hors / thenne when they sawe the kynge fast in the gyaunts armes / they came and losed hym / And thenne the kynge commaunded syr kaye to symte of the gyaunts hede / and to sette it vpon a truncheon of a spere / and bere it to syr hewel / and telle hym that his enemy was slayne. (Book V, chap. v.)

Malory's sources were French and English, and to them he added detail and his own interpretation.

Although Arthur figures as a successful general in the "Historia Britonum" (c. 810) by Nennius, who expanded and redacted preexisting compilations, Geoffrey of Monmouth is usually called the father of Arthurian romance. Geoffrey, for his "Historia Regum Britanniae," published about 1136, gathered his material, according to L. C. Paton, from "episodes in the chronicles of his contemporaries, William of Malmesbury, and Henry of Huntingdon, from ancient Celtic records, the legends of Celtic saints, Celtic myth, Biblical history, classical and Scandinavian stories, the universal stock of folk-tales, local British tradition, the Carolingian cycle, familiar facts of general history, and from events in the life about him."

In chapter III, Book X, of the "Historia," King Arthur meets on Mount Michael the giant who had captured Helena, niece of Duke Hoel.

> The King forthwith unsheathed his sword, and covering him with his shield, hurried as swiftly as hurry he might to be beforehand with him, and prevent his getting hold of the club. But the giant, not unaware of his intentions, had already clutched it and smote the King upon the cover of his shield with such a buffet as that the sound of the stroke filled the whole shore, and did utterly deafen his ears. But Arthur, thereupon blazing out into bitter wrath, lifted his sword and dealt him a wound upon his forehead, from whence the blood gushed forth over his face and eyes in such sort as well-nigh blinded his sight. Howbeit, the blow was not deadly, for he had warded his forehead with his club in such wise as to scape being killed outright. Natheless blinded as he was with the blood welling forth, again he cometh on more fiercely than ever, and as a wild boar rusheth from his lay upon a huntsman, so thrust he in within the sweep of Arthur's sword, gripped him by the loins, and forced him to his knees upon the ground. Howbeit, Arthur, nothing daunted, soon slipped from out his clutches, and swiftly bestirring him with his sword, hacked the accursed monster, first in one place and then in another, and gave him no respite until at last he smote him a deadly buffet on the head, and buried the whole breadth of his sword in his brain-pan. The abhorred beast roared aloud and dropped with a mighty crash like an oak torn up by the roots in the fury of the winds. Thereupon the King brake out on laughing, bidding Bedevere strike off his head and give it to one of the squires to carry to the camp as a rare show for sightseers.

FORTEY'S HALFPENNY EDITION.

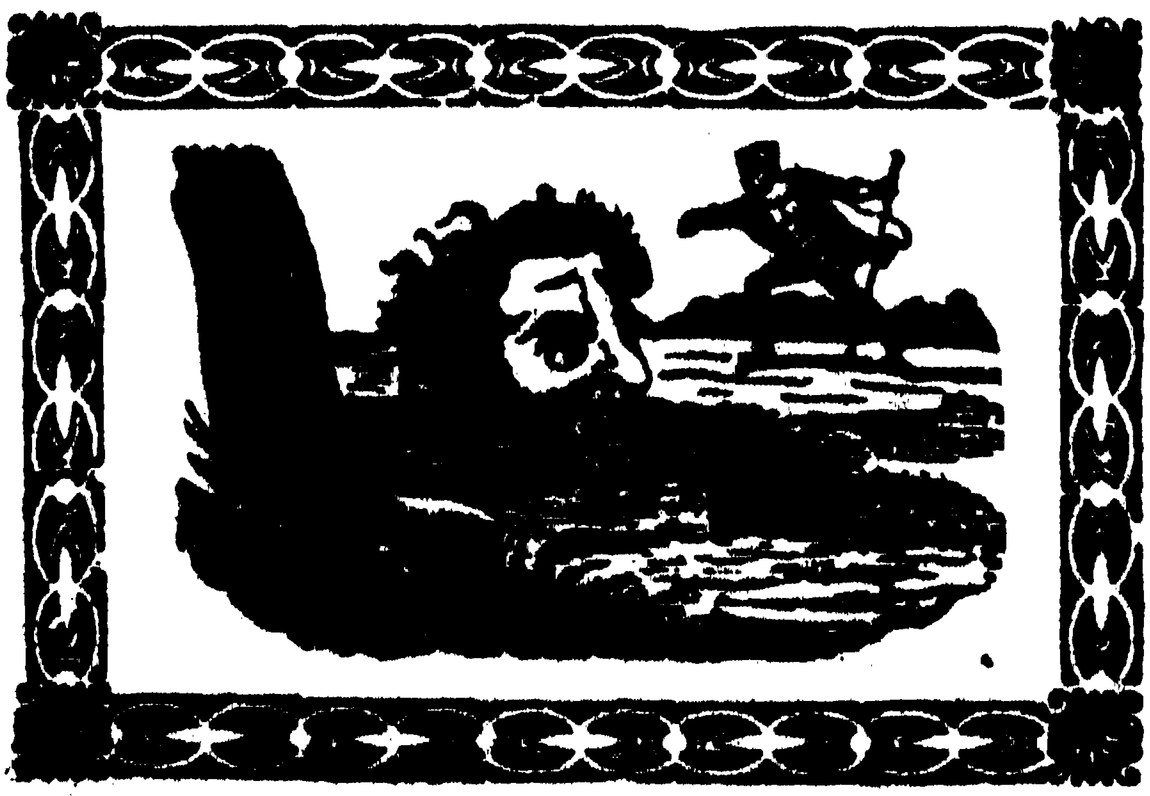
THE HISTORY OF

JACK

THE

GIANT

KILLER.



LONDON:
Printed and Published at W. S. FORTEY'S Wholesale Juvenile Book Warehouse, 2 & 3, Monmouth Court, Bloomsbury. W.C.

TITLE PAGE OF FORTEY'S "HISTORY OF JACK THE GIANT KILLER," PUBLISHED ABOUT 1840.

The English version of Jack the Giant Killer is also said to have been adapted from the story of Corineus the Trojan, found in Geoffrey's "History of the Kings of Britain."

It has been stated that the earliest form of Jack the Giant Killer in western lore is probably the account of Thor and the giant Skrymir, found in the collection of the celebrated Icelandic historian, Snorri Sturluson, known as "Edda Snorra" (between 1140 and 1160). In this old Scandinavian folk-tale entitled "Thor's Journey to the Land of Giants," Thor becomes enraged because he can not open the giant's bag, which contains their provisions, and hurls his hammer at the head of the sleeping giant. This awakens Skrymir, who asks if a leaf has not fallen upon him. A second time Thor uses his hammer, driving it into the giant's brain, upon which the giant

4 HISTORY OF

terror; on entering the wall of the castle, he found the floor covered withs culls and bones of the dead. He then brought him into a large parlour, where lay the blood and quarters of ome lately slain; and in the next room were hearts and livers; when the Giant to terrify him, said that men's hearts were his favourite diet, which most commonly he ate with pepper and vinegar; adding, that he did not question but his heart would make him a curious breakfast.

This saying, he locked up poor Jack in an upper room, leaving him there, while he went to fetch another Giant, who lived in the same wood, that he might partake of the destruction of honest Jack.

Jack, ready to run distracted, went to the window, and opened the casement, aud beheld both of the two giants coming together. Now, said Jack to himself, my death or deliverance is at hand. There were two strong cords in the room by him, at the end of each of which he made a noose, and as the giants were unlocking the gate, he threw one of the ropes over each of the giants' heads, and then threw the other end across a beam, where he pulled with all his might, till he had throttled them. Aud then, fastening the rope to a beam, he beheld the two giants both black in the face, and sliding down the rope, he came to the heads of the helpless

JACK THE GIANT-KILLER. 5

giants, who could not defend themselves; and, drawing his own sword, he slew them both, and so delivered himself from their intended cruelty. Then taking the bunch of keys, he entered the castle, where he found three ladies tied up by the hair of their heads, and almost starved to death, who told Jack that their husbands had been slain by the giant, and who had been kept many days without food, in order to force them to eat the fle-h of their murdered husbands, which they could not do if they were starved to death. Sweet ladies said Jack, I have now destroyed the monster and his brutal brother, by which means I have obtained your liberties. This said, he presented them the keys, and proceeded on his journey to Wales.

Jack having got but little money, he thought it prudent to travel hard; but, losing his way, he was benighted, and could not get a place of entertainment, until, coming to a valley between two hills, he found a large house in a lonesome place, and by reason of his present necessity, he took courage to knock at the gate; but, to his amasement, out came a monstrous giant with two heads. He did not seem so fiery as the other two, for he was a Welch giant, and all that he did was by secret malice, under the false shew of friendship. On Jack telling him his condition, he bade him welcome

PAGES 4 AND 5 OF FORTEY'S "HISTORY OF JACK THE GIANT KILLER."

again awakens and asks if an acorn has not fallen on his head. A third time, Thor buries his hammer in the giant's cheek, with the result that Skrymir again is aroused from his sleep and asks if some moss has not fallen on him. Later in the tale it appears that in every case the sly Skrymir had substituted a rock for his person and so escaped the blows from Thor's hammer. This story is similar to that of Jack's adventure with the Welsh giant, and Ashton cites this similarity as part of the proof of the northern origin of Jack the Giant Killer. As for Jack's coat which rendered him invisible, his cap of knowledge, his shoes of swiftness and his miraculously sharp sword, Ashton states:

To show the northern origin of this tale, it is only necessary to point out that the coat is identical with the magic garment known in ancient German as the "Nebel Kappe," or cloud cloak, fabled to belong to King Alberich and the other dwarfs of the Teutonic Cycle of Romance, who, clad therein, could walk invisible. To them also belongs the "Tarn Hut," or Hat of Darkness. Velent, the smith of the Edda of Sæmund, forged a "Sword of Sharpness," which in the Wilkina Saga is called Balmung. It was so sharp that when Velent cleft his rival, Æmilius, it merely seemed to the latter like cold water running down him. "Shake thyself," said Velent. He did so, and fell in two halves, one on each side of the chair. The Shoes of Swiftness were worn by Loke when he escaped from Valhalla.

Thomas Keightley, who wrote long before Ashton, called attention to the fact that Jack's strategy, in substituting a stick of wood for himself during his adventure with the Welsh giant, was not

JACK KILLS BLUNDERBORE.

JACK STRANGLES THE GIANTS.

JACK'S ARTFULNESS.

JACK SHOWS THE GIANT A TRICK.

THE GIANT AND HIS PRISONERS.

JACK SLICES OFF THE GIANT'S NOSE.

ILLUSTRATIONS FROM BYGONE EDITIONS OF JACK THE GIANT KILLER.

peculiar to English giant-killers, but was found also in the folk-tales of other countries. In addition to the tactics of Skrymir, Keightley mentions the German "Brave Tailorling" ("Das tapfere Schneiderlein") which deals with the adventures of a little tailor who had killed seven flies on his bread, all at one blow, and who was so proud of this that he wanted the whole world to know about it, although he was careful to state only that he had killed seven, not specifying what the seven had been. At the beginning of his travels he met a giant sitting on the top of a mountain, and after a comparison of feats in which both giant and tailor performed and in which the tailor came off best, by reason of his tricks, the giant invited him to spend the night in his cave. The tailor was smart enough not to lie in the bed but to hide in a corner instead, and it was well that he did so, for the giant came in during the night and with an iron club struck the bed a blow that sent the club through it. Keightley, after calling attention to the similar strategy of the giant Skrymir and the little tailor, suggests the possibility of Jack the Giant Killer having been brought into England by Anglo-Saxon or Danish ancestors by way of "Thor's Journey to the Land of Giants," and Sir Walter Scott believed that "Jack" landed in England "from

the very same keels and warships which conveyed Hengist and Horsa, and Ebba the Saxon,''[1] supposedly about 450–455. However, the device of "substitution" is found in the folk-tales of more distant countries, and this is noted by Keightley.

In the Persian story, "Ameen of Isfahân and the Ghool," supposedly from India, Ameen saves his life by the substitution of a pillow for himself, in bed, escaping a terrible blow from the Ghool's walking-stick which was as big as the trunk of a tree.

In Perrault's tale of "L'Adroite Princesse," Finetta manufactures a straw figure into which she puts a bladder of blood. Substituting this figure for herself, in bed, she escapes the sword of the prince. And in Giambattista Basile's "Il Pentamerone" (c. 1637, Naples), "Sapia the Glutton," heroine of the tale so called, makes a figure of pastry and sugar scented with musk. This she places between the bed sheets and then hides herself behind a screen. The prince Torre, whom Sapia had given much cause for worry, enters with murder in his heart and plunges a dagger into the confection. So terrible was he, that, desiring even to drink her blood, he licks the dagger, but tasting its sweetness and the scent of musk, he is overcome for having killed so sweet a girl and would have taken his own life on the spot had not Sapia come forth to console him.

According to Keightley, most of the circumstances of "Ameen of Isfahân and the Ghool," of "The Brave Tailorling" and of "The Goat and the Lion," one of the stories in "The Panchatantra," which assumed shape in India and spread through Persia, Arabia, Syria and European countries and whose already old tales were supposedly composed about 200 B. C. in Kashmir, are found in "The Lion and the Ass," one of the tales in Straparola's "Pleasant Nights." From this one may assume that the fable of "The Lion and the Ass" originated in India.

In "Notes and Queries" (3rd Ser. IX, pp. 515–16, 1866), H. C. advanced the opinion that the earliest form of Jack the Giant Killer in Western folklore was probably the tale of Thor and the giant Skrymir, and stated that in the East every Hindu school-boy knew of Beeman, one of the fine Pandus, and his giant-killing adventures, the Pandus being first mentioned in the "Mahabharata," written at least 240 B. C. He also stated that the words, "Fe, fi, fo, fum, I smell the blood of a man," were paralleled in a couplet spoken by a giantess in a Mohammedan tale called "Sunebal [golden-haired] and the Ogress," which he heard related in India.

Although there is a stronger human element in Jack the Giant Killer than in the strictly eastern tales of fairies, genii, etc., giant legends are common in Asia and Europe. The cannibalistic skin-clothed, stupid giants, armed with clubs and stones, may have been the savage tribes transformed into giants in the folk-lore of those who conquered them.

From the summary herewith presented, one may make the somewhat indefinite statement that Jack the Giant Killer is apparently of Indo-European origin and was probably introduced into England during the Saxon invasion.

Folk-tale happenings are widely distributed. Carried from one tribe to another and from one country to another and from one continent to another, there is often in the tale little intraneous evidence to indicate the origin either of native or foreign parts. European folk-tales are said to be remarkably uniform in content, although differing in speech and local color. Boas states that the frameworks of myths and folk-tales are almost exclusively made up of events

[1] "The Child and His Book," by Mrs. E. M. Field (London, 1892).

that reflect the occurrences of human life, especially those that agitate the emotions. The extremely fanciful character of the tales may be ordinary wishes or amplifications of our experiences, such as the smallness of dwarfs, bigness of giants or manifestation of objects of fear. Boas calls attention to the limited power of imagination in man and the tendency to use the old stock of inventive occurrences rather than to think up new ones, and also to the fact that the highly embroidered, more complex and locally colored tales are the result of more thought and attention being given to them by priests, poets and deeply interested persons.

Numerous English editions of Jack the Giant Killer have appeared since the one referred to, in the beginning of this paper, as having been published at Newcastle in 1711. Many are illustrated with delightfully crude woodcuts, sometimes frightfully and carelessly colored in red, blue, green and yellow, such as the Fortey (1850?) and the Otley editions. Bound in colored paper covers with their pictures of giants in various poses and succumbing to Jack's ingenuity, they must have delighted their juvenile readers immensely. Although the various early editions differ from each other, sometimes in their wording, their omissions and their abridgments, the versions are, for the most part, the same, and the essentials of the tale are retained. In some of the early editions, especially those intended for small children, Jack's sprightly conversation and exchange of wit with a local clergyman, in the opening part of the tale, are omitted. Nowadays one may purchase beautifully printed, bound copies of Jack the Giant Killer, illustrated in colors by such artists as Margaret Campbell Hoopes, Hugh Thomson, H. M. Brock, Margaret W. Tarrant, Margaret Evans Price and others, and it is interesting to note the conceptions of the various illustrators over the two-hundred-year period. For the most part, the giants have maintained their brutish, unintelligent appearance, and Jack remains a dapper hero. These modern versions are essentially like the older ones. Here and there, expressions have been changed or omitted, and killings have been softened somewhat; sometimes the tales are abridged, and on the whole they are a little less concerned with all of the details found in the chapbook versions. During the passage of time the few coarse expressions of the early accounts have disappeared.

Although Jack the Giant Killer is still holding his own—and undoubtedly will continue to do so—at times one is fearful that he is being crowded out by the very large and varied amount of other types of children's reading matter that is so apparent in the bookstores of to-day.

THE STORY OF THE LIBRARY AT LOUVAIN

By Dr. FRANK PIERREPONT GRAVES

NEW YORK STATE COMMISSIONER OF EDUCATION AND CARNEGIE VISITING PROFESSOR OF INTERNATIONAL RELATIONS

To judge from the press, American interest in the new library at the University of Louvain has been centered in the dispute over a proposed inscription on the balustrade. This inscription read, *Furore teutonico diruta, dono americano restituta*, which was commonly translated, "Destroyed by German fury and restored by American generosity," and the controversy raised the old question of "to be or not to be." To the university authorities it seemed abhorrent to immortalize in stone the fact that the building had been "destroyed by German fury," and thus maintain forever the spirit of war. As a matter of fact, too, the university building that had actually been destroyed was in quite another part of the town and had already been marked with an inscription.

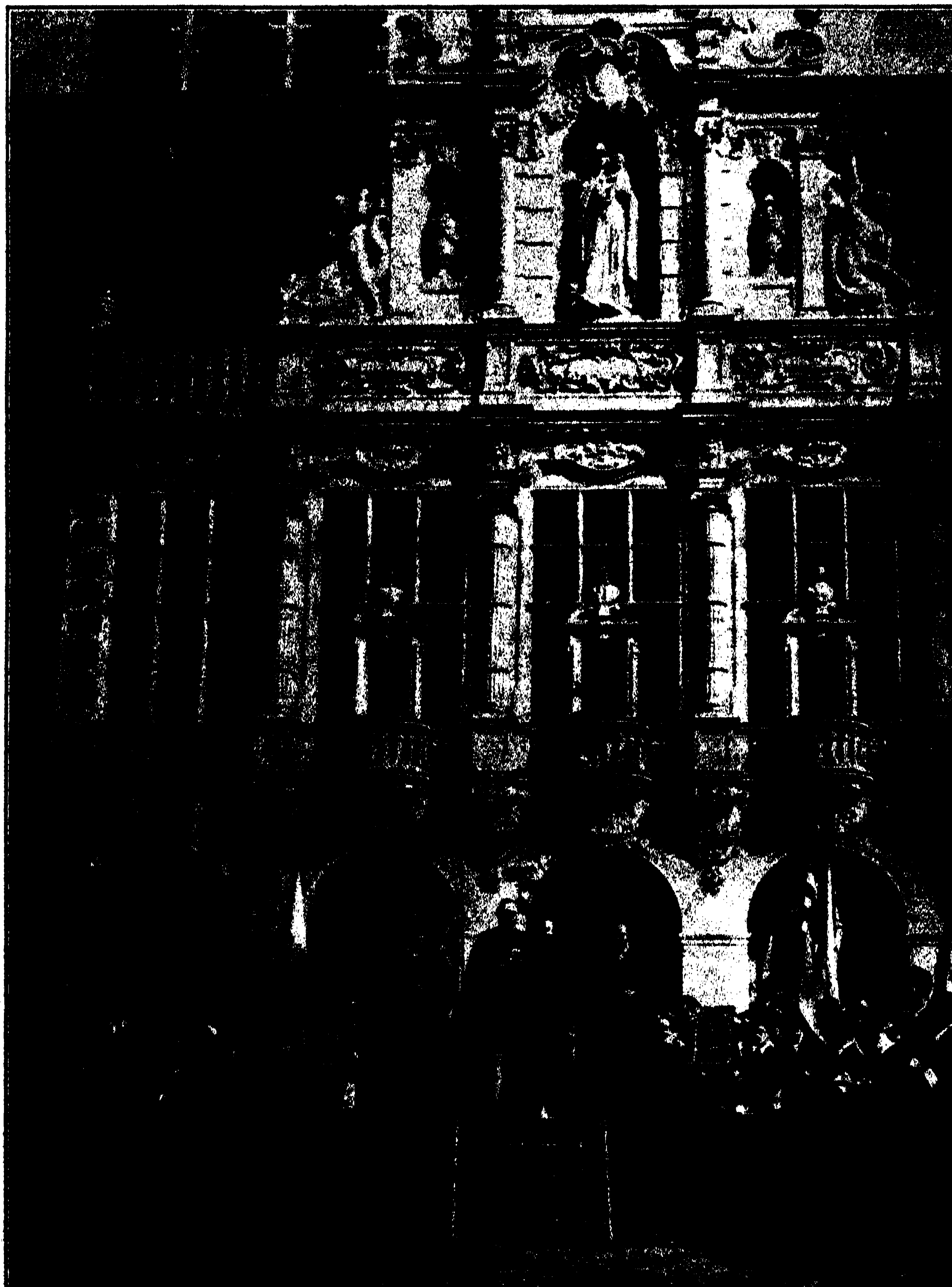
Representatives of the American donors were at one with the university in opposing such a perpetuation of hate. In addition, most of them found the second clause almost as distasteful as the first. Whatever other nations may think of us, Americans in general do not desire to blazon their good deeds from the housetops. The National Committee for the Restoration of Louvain, the Carnegie Endowment for International Peace and the Commission for Relief in Belgium, which had collectively made the building possible, all held that the decision as to what the character of the building should be rested entirely in the jurisdiction of the university authorities, and as far as American contributors were concerned, an inscription of the sort proposed could not possibly meet with approval.

But the talented architect of the library, Whitney Warren, could not see matters in this light. He held that the withdrawal or modification of the inscription would ruin his building and that as its artificer he had absolute right to determine every portion of its appearance. To justify the form of the inscription, he declared that it had been approved by Cardinal Mercier himself, who first inspired the restoration of the university library and whose name was a *shibboleth* to Americans and Belgians alike. The nationalists among the Belgians at once espoused the cause of the architect and violently attacked the rector of the university in public print.

The *impasse* that followed this serious difference of opinion has proven most spectacular and has attracted the attention of Americans everywhere. But the controversy over the inscription was in reality a small incident in a great international event. Of completely overshadowing importance were the sympathy and aid elicited for the stricken university not only from the United States but from the entire civilized world as well. The bitterness engendered, regrettable as it was, sinks into insignificance when compared with the dedication of such a magnificent building, testifying to our admiration for Louvain and enabling it to continue its work through the coming centuries. The story is worth narrating in all its picturesque setting.

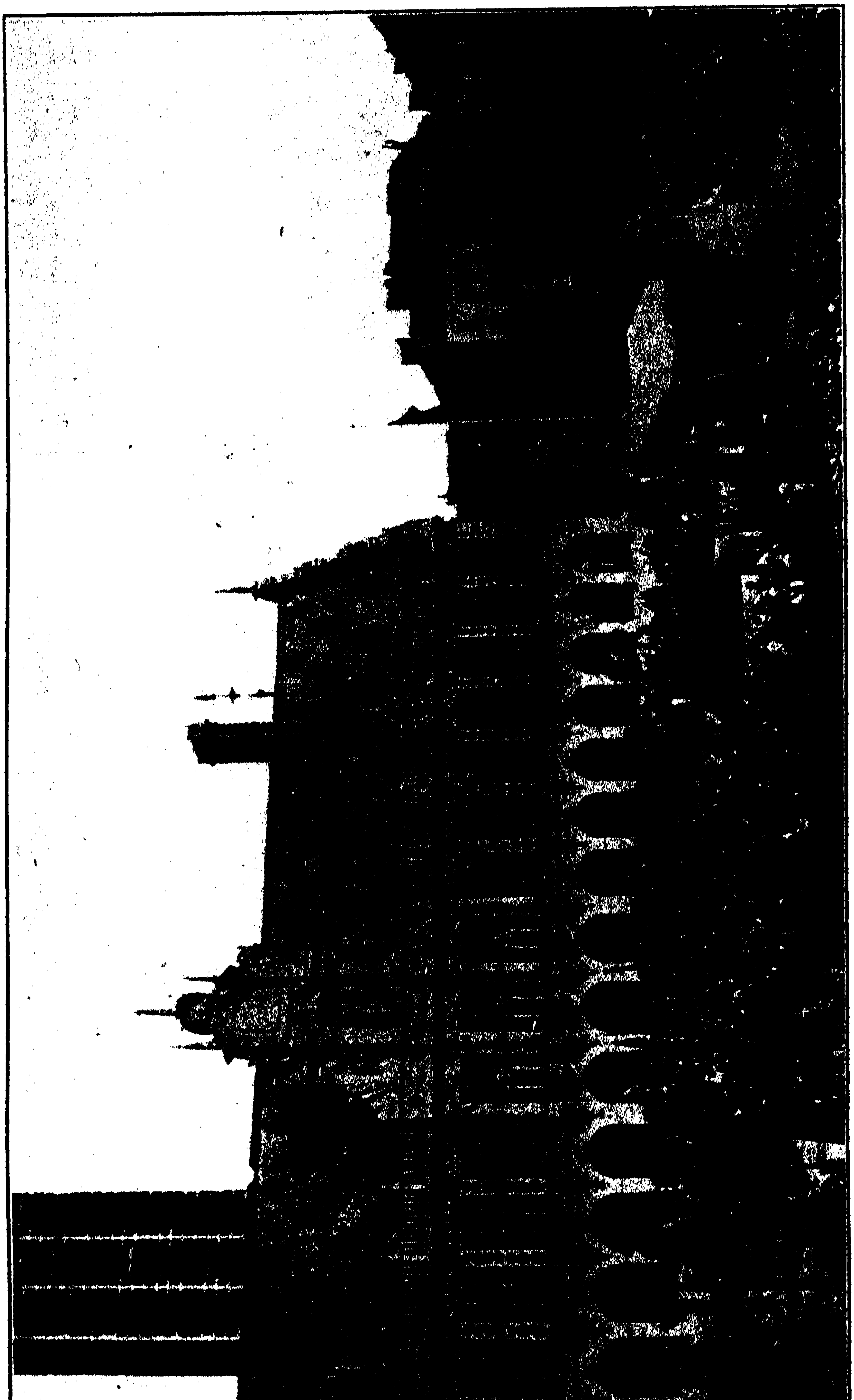
I

In the first place, no one would think of minimizing the outrage and loss to civilization connected with the destruction of Louvain and its famous uni-



THE PRESENTATION OF THE OFFICIAL ADDRESS OF THANKS

THE CARDINAL, PRESIDENT EX-OFFICIO OF THE UNIVERSITY BOARD OF TRUSTEES, IS SPEAKING IN FRONT OF THE BUILDING AND OPPOSITE THE TRIBUNE OF HONOR. THE PHOTOGRAPH ALSO AFFORDS A NEAR VIEW OF THE ORNAMENTATION OF THE FAÇADE.



THE LIBRARY BUILDING AT LOUVAIN

MADE POSSIBLE THROUGH AMERICAN CONTRIBUTORS AND THE GENIUS OF WHITNEY WARREN. THIS PICTURE IS A WIDE WORLD PHOTO. THE OTHER ILLUSTRATIONS WERE ORIGINALLY PUBLISHED IN *Le Patriote Illustré* OF BRUSSELS.

versity. The magnitude of the calamity can scarcely be overestimated. For nearly five hundred years before the invasion of Belgium the University of Louvain had been a notable center in every advanced movement of education. It was, for example, among the earliest of the universities to have its medieval curriculum transformed by the spirit of humanism. For many years that wandering scholar of the Low Countries, the great Desiderius Erasmus, here found sympathetic friends, and by his teaching raised Louvain to a position of supremacy second only to Paris. Other distinguished humanists, like Vives, Rescius and Clenard, were attracted by the reputation he gave the institution, and toward the close of the sixteenth century, largely through the lectures of the famous professor, Justus Lipsius, Louvain came to have fifty-two colleges and some six thousand students.

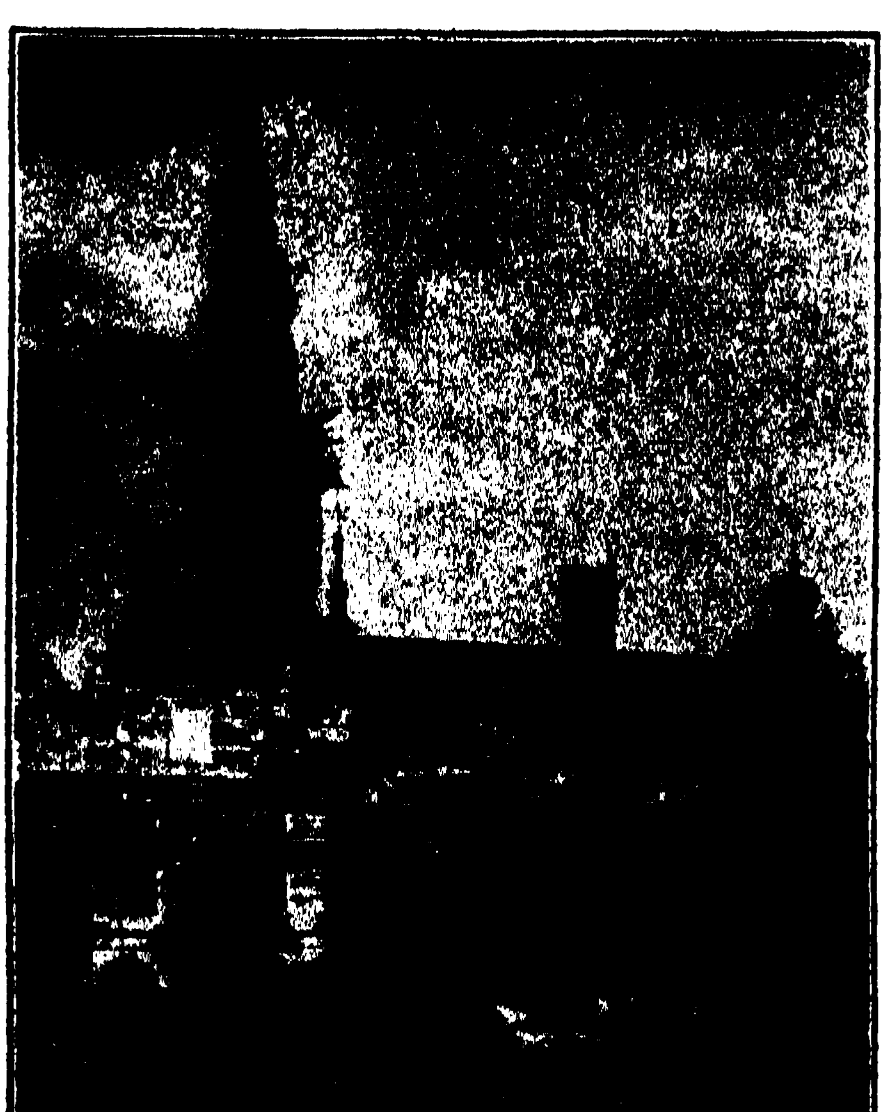
Similarly, during every succeeding epoch in educational progress, this institution became the home of some of the more reputed scholars of the time. Here, when science began to awaken, taught Vesalius, the founder of modern anatomy, Dodoens, the botanist, and Mercator, who left a lasting impression upon geography. Over the destinies of Louvain in the seventeenth century presided Cornelius Jansen, who formulated one of the few unique systems of thought the world has known. While during the next century the university lost in numbers and reputation and was closed for a time during the disturbed period of the French Revolution, it was revived during the nineteenth century and largely recovered its high standing in science, literature and politics. Its scientific investigations have now a wide repute. While poorly endowed, it has for years maintained the largest institute of cancer research in the world, and ranks among the leading universities in the advancement of engineering and agriculture. It has become the nursery of modern Belgian literature, and during their student days nurtured such men as Verhaeren, Geroud, Waller and Van Arenburgh. And so thorough has been its training that its graduates have continually held many of the highest public offices in Belgium.

Through all this progress and intellectual leadership of the university its library has necessarily been a workshop and a great center of inspiration. At the time of its destruction it contained but a quarter of a million volumes, which would not in our country mark it as one of the largest libraries, but it must be remembered that these works had been accumulating for five centuries and in many instances were world famous. Among them were a thousand rare manuscripts of the early Middle Ages, hundreds of *incunabula*, the precious "books of hours," early publications of the first reformers, historic politico-religious pamphlets, polemic writings of the seventeenth century, successive editions of the Bible and many other rare works impossible to replace. Moreover, since Louvain was training about one half of the students of Belgium and hundreds from other countries, the injury wrought by the invasion could be paralleled only by the destruction of the libraries of a dozen or two of our greatest universities.

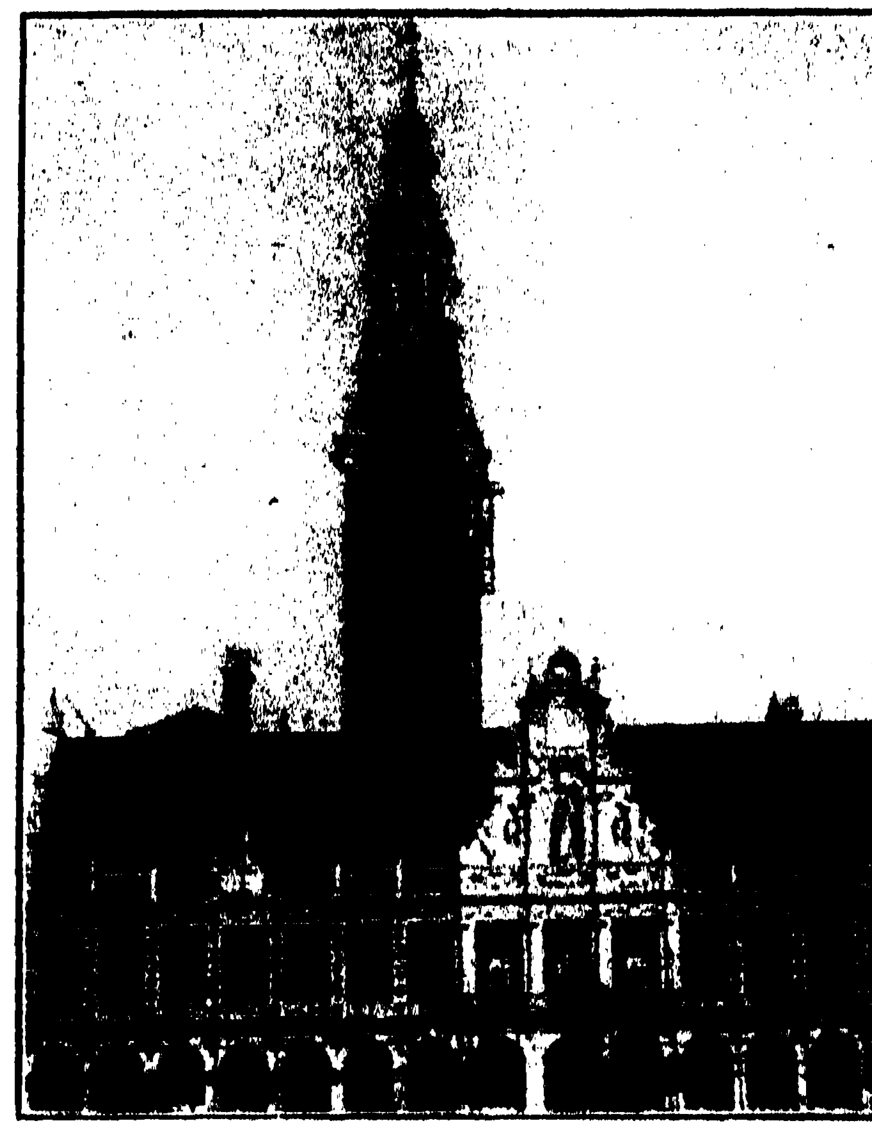
This destruction may be considered an act of "German fury" if you will, but it is only typical of the extremes to which the war madness will go. It is a demonstration rather of the utter futility of warfare and of the ruin that falls upon mankind when the primitive instincts and passions of our infrahuman ancestry are once allowed to slip their leash. The destruction of the library at Louvain served absolutely no purpose, not even that of the exigencies of war or of robbery and pillage. It was the natural offspring of the war demon, and rendered the civilized world furious.

II

Only a short time after the destruction, the sympathy and common humanity of the United States and other civilized nations began to manifest themselves. Efforts at reparation were started almost immediately. As an outcome the *Oeuvre International de Louvain* was formed, with national committees in each country, and by the time that the first wing of the new library was completed the books ready for its shelves had already run into hundreds of thousands. The honor of constructing a suitable new building was conceded to America. The first half million for this purpose was raised by our National Committee and the Carnegie Endowment, under the direction of Nicholas Murray Butler, mostly through small contributions, but gifts of considerable size had later to be raised to complete the necessary million and the hundred thousand additional needed for upkeep. Here the largest contribution was made by the Commission for Relief in Belgium, of which Herbert Hoover was the president.



A VIEW OF THE TOWER FROM THE SIDE



A VIEW OF THE TOWER FROM THE FRONT

The building resulting from these donations is a triumph in architecture. By a happy thought it has been designed in complete harmony with the fifteenth and sixteenth century aspect of the town, and while from its great architectural beauty and its imposing site on the *Place du Peuple* it dominates the surrounding country, it fits easily and naturally into the perspective. The architect has laid aside all American traditions and likewise avoided the temptation to indulge in columns and classic orders, and has created a building in the style of the Flemish Renaissance. Its characteristic feature is the wide vaulted *loggia*, or covered arcade, with seventeen arches, which underlies the principal façade.

The façade itself is adorned with sculptures, bas-reliefs, busts and statues, which are both memorial and symbolic. The central *motif* is the armed Virgin. Clad in a cuirass, she wears on her head the poilu's helmet, and her right hand rests upon the sword of the Crusaders, while her left supports the Holy Child. Our Lady of Victories is flanked by

figures of St. George and St. Michael crushing evil spirits. Above these decorations is a bas-relief representing the destruction of the former library building, while underneath, above doors leading to three outside pulpits, are busts of the war heroes—King Albert, Cardinal Mercier and Queen Elizabeth. The graceful tower, 275 feet in height, with the carillon given by the engineers, typifies the voice of the university—the voice of truth. Every hour the bells play a few bars from the Star-spangled Banner, the Brabançonne, the Marseillaise, or other national airs of the Allies.

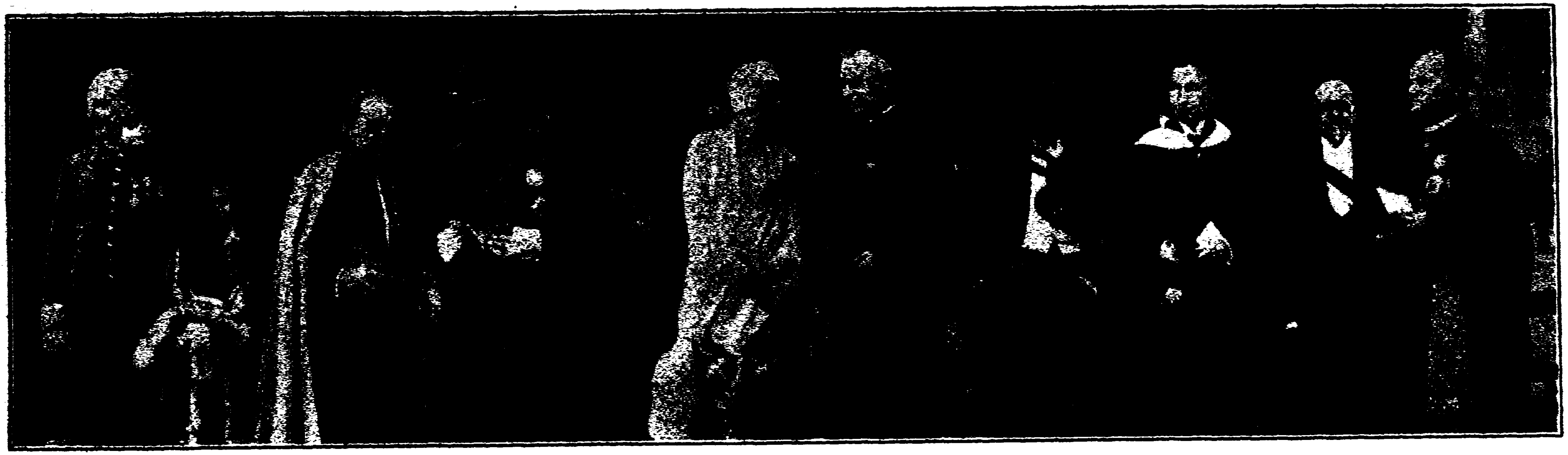
III

The dedication of this most appropriate building was, out of compliment to the United States, set for the fourth of July. As the visitor entered Louvain on that gala day, it appeared ablaze with decoration. The emblems of the United States and France were everywhere intermingled with those of Belgium and the University of Louvain. Nearly every house in the medieval city bore at least two or three flags. The façade of the richly fretted Gothic town hall was a symphony of color. At the *Place du Peuple*, in front of the new library, where the ceremonies were to be held, workmen were until the last moment beautifying the grounds and preparing them for the celebration. Facing south toward the library there had been erected for the notables of the occasion a covered "tribune" of honor, fitted out with purple velvet and gold fringe. Opposite the tribune and much nearer the library a platform had been built for the speakers and equipped with a microphone that carried to all parts of the grounds. In the center of the enclosure, between the pavilion and the speakers' stand, a circular plot of palm trees had been tastefully arranged. On the right and left of the tribune and at right angles to it hundreds of chairs were reserved for the Belgian civil, ecclesiastical, military and academic authorities, and for the innumerable delegates and invited guests from other countries.

The colorful academic parade began at two o'clock. It was preceded by an escort of mounted police and companies of gendarmes and soldiery. This vanguard was followed, according to established custom, by a group of six heralds, all wearing steel helmets, blue tunics, coats of mail and leather leggings. Following them came the mace bearers, always so imposing a sight in the processions of old Continental universities. Then marched the delegates from various universities, Belgian and foreign, with the Americans in front. Last in the procession Monsignor Ladeuze appeared in full rectorial dress of black and red velvet, accompanied by Cardinal Van Roey, president *ex officio* of the University Board of Trustees and apostolic successor of the great Mercier.

The procession wound its way through the crooked narrow streets from Convocation Hall to the new building through a double line of honor composed of students of the university. When the library was reached, a tumultuous cheer burst from the throats of three thousand students, "*Vive le recteur!*" which was intended to voice their approval of his course with reference to the inscription and their adherence to constituted authority. On the front row of the tribune the rector took his place, and then in order came the American ambassador, the cardinal, the papal nuncio and the burgomaster of Louvain. Two chairs between the cardinal and the nuncio were left vacant for the royal personages, who were shortly to appear. The other chairs of the tribune were occupied by members of the Belgian cabinet, the French ambassador, the Belgian ambassador to Paris and the speakers of the day. Among the guests in the chairs near the tribune were the ambas-

THE GATHERING AT THE DEDICATION (LOOKING TOWARD THE TRIBUNE OF HONOR)



OCCUPANTS OF THE TRIBUNE OF HONOR

LEFT TO RIGHT. FIRST ROW: M. VAN DER VAEREN, BURGOMASTER OF LOUVAIN; MONSIGNOR MICARA, PAPAL NUNCIO; CROWN PRINCE LEOPOLD; CROWN PRINCESS ASTRID; HIS EMINENCE, ERNESTO CARDINAL VAN ROEY; HON. HUGH S. GIBSON, AMBASSADOR OF THE UNITED STATES; MONSIGNOR LADEUZE, RECTOR OF THE UNIVERSITY. SECOND ROW: CABINET OFFICERS, SHOWING ESPECIALLY MINISTERS VAUTHIER AND CARNAY. THIRD ROW: DIPLOMATS AND SPEAKERS, WITH DR. GRAVES, THE AUTHOR OF THIS ARTICLE, BETWEEN THE CARDINAL AND THE PRINCESS.

sadors or ministers from a dozen other countries, the governors of the various Belgian provinces, the bishops of the archdiocese, the secretary of the Vatican library, generals in the Belgian army and the governor of the National Bank. After all these had been seated, the Theban trumpets sounded a fanfare and an automobile drove up with the crown prince and princess (the king and queen being absent in the Congo), who were then conducted to their places on the tribune amid the storms of applause from enthusiastic students and others.

IV

It was now two-thirty and the program began. First came the benediction upon the new building by the cardinal, assisted by the Belgian bishops. Invested with mitre and crosier the primate mounted the speakers' platform, faced the library and intoned the liturgical prayers. The responses were given by students in the Seminary of Malines, and the chants were magnified and diffused by a loud speaker fixed in the tower of the library. He then made a tour of both the exterior and the inside of the building, sprinkling the walls and purifying them with incense. As a final step the youngest of the bishops performed the rather perilous duty of ascending the spiral staircase of the tower and blessing the bells. At the conclusion of this ceremony the carillon pealed forth a chant of glory and resurrection and a select choir from the public schools raised sweet young voices in a *Cantate* of Peter Benoit's.

Then came the addresses by representatives of the American donors. Ambassador Hugh S. Gibson, representing the larger givers, spoke first. After his address he delivered to the rector the golden key to the new library. This was the signal for immense applause and from all sides came vigorous cries of "*Vive l'Amerique!*" From the summit of the tower the Theban trumpets blared forth the Star-spangled Banner, the carillon played it and a fine baritone voice sang it, with the school children joining in the chorus. The other speakers were the writer of this article, who represented the small givers; M. Alfred Rébelliau, President of the International Association, which had done so much for the restoration of the university and its library; M. Georges Goyau, who in the name of university professors of France expressed sentiments of intellectual sympathy and fraternity; Edward Dean Adams, who represented the American engineers giving the carillon; and Cardinal Van Roey, who expressed the thanks of the university.

Following the dedication, a bust of Herbert Hoover, carved by a young Belgo-American sculptor, Suzanne Silvercruys Farnam, was unveiled on the first floor of the new library by Edgar Rickard, on behalf of the Commission for Relief in Belgium. Then came the banquet, which was set in the great reading-rooms of the new library, and at which six hundred guests—half of them American—were present. The occasion was enlivened by renditions of the great carillons, broadcasted from various parts of Belgium and foreign countries, and by a most eloquent toast of welcome and thanks to the United States by Rector Ladeuze. After this the party adjourned to the seats outside and listened for an hour to a marvelous concert consisting of selections on the carillon performed by Denyn of Malines, the most celebrated player in the world, and of songs rendered by a choir from the Royal Conservatory at Liége, directed by the great Gérome. The day closed with fireworks and the illumination of the tower.

Such in brief is the story of the new library dedicated at the University of Louvain. As a matter of fact, the difficulties over the inscription have been

exaggerated. Nothing further is likely to occur. It is natural for some of the more impulsive Belgians, who vividly recall the circumstances under which the University of Louvain was ruthlessly destroyed, to act as they have. But the war is over and should never be revived.

The affair goes deeper and includes far more than a squabble over the form of an inscription. It involves the history of a university world renowned and an intellectual force for a half millennium of civilization. It embodies a substantial expression of sympathy and cooperation from most of the great nations of modern times. It depicts an effort not to forget war injuries, but to rise above them. It repudiates the spirit of hatred and urges us forward toward the attainment of permanent peace and the more complete civilization of the future. As an international event the celebration at Louvain deserves to rank with the conferences at The Hague, Geneva and Locarno, and its underlying spirit matches with that of the World Court, the League of Nations and the proposed disarmaments.

TERMITES AND ARCHITECTURE

By THOS. E. SNYDER

BUREAU OF ENTOMOLOGY, U. S. DEPARTMENT OF AGRICULTURE

TERMITES were architects long before the advent of man on earth and their hard earth-like carton or mound nests are built in trees (as lived arboreal man), or in excavations below ground (as the cave man), or as low, hut-like mounds or lofty skyscrapers on and above the ground (as present man). Termites have not only constructed primitive rammed earth or Picazo and "'dobe" houses but well-ventilated and rain-shedding pagodas (Figs. 1–7).

—*Photograph by J. Zetek*

FIG. 1. "NIGGERHEAD" ARBOREAL CARTON TREE NEST OF *Nasutitermes ephratae* HOLMGREN, ABOUT 3 FT. × 2½ FT. ON TREE. PANAMA.

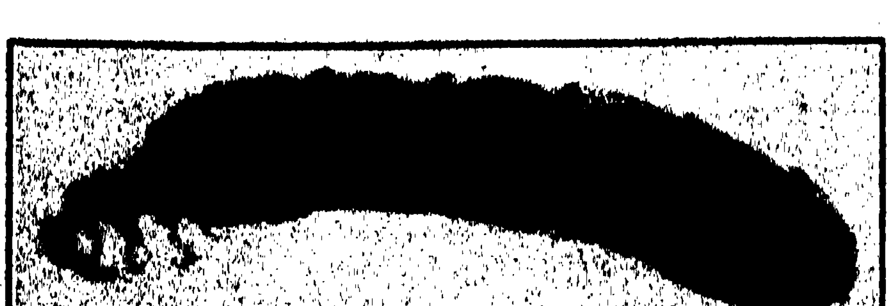


FIG. 2. QUEEN FROM SIMILAR NEST. ABOUT THREE AND A HALF TIMES NATURAL SIZE.

Natives of the Transvaal, South Africa, according to Claude Fuller, have venerated certain termite mounds for hundreds of years; the mounds have remained unchanged through the ages.

With this long experience as practical and successful builders, wood-destroying termites have no difficulty in finding weak points in the construction of the buildings of man. Driven from their homes in the forest by land clearing and civilization, termites have been destructive to man's handiwork. Such ability of termites to destroy is recognized by our colored folk of the southern states who hang "white ants" in a bag around the neck of a teething child to help it "cut" teeth. Did our Negroes bring this folk lore from their original home in tropical Africa, where termites are much more common and destructive?

Aside from the usual destruction of buildings and contents, such as furniture, clothing, shoes, books and paper, timber in contact with the ground, and living vegetation, some odd cases of injury are recorded. Termites are with us both while we are alive and after we are dead. Damage to mummies, coffins in graves, human skulls and bones, ivory elephant tusks, wooden ice houses full of ice, where the woodwork and sawdust insulation were burrowed through, wooden ice boxes containing human cadavers with the strong odor of formaldehyde present, lead-sheathed and rubber-insulated cables in underground wooden conduits, woodwork of wells far below ground, wooden silos and water tanks, the penetration of lime mortar between bricks in foundations and tar and tar paper waterproofing for wood (Fig. 8) have occurred.

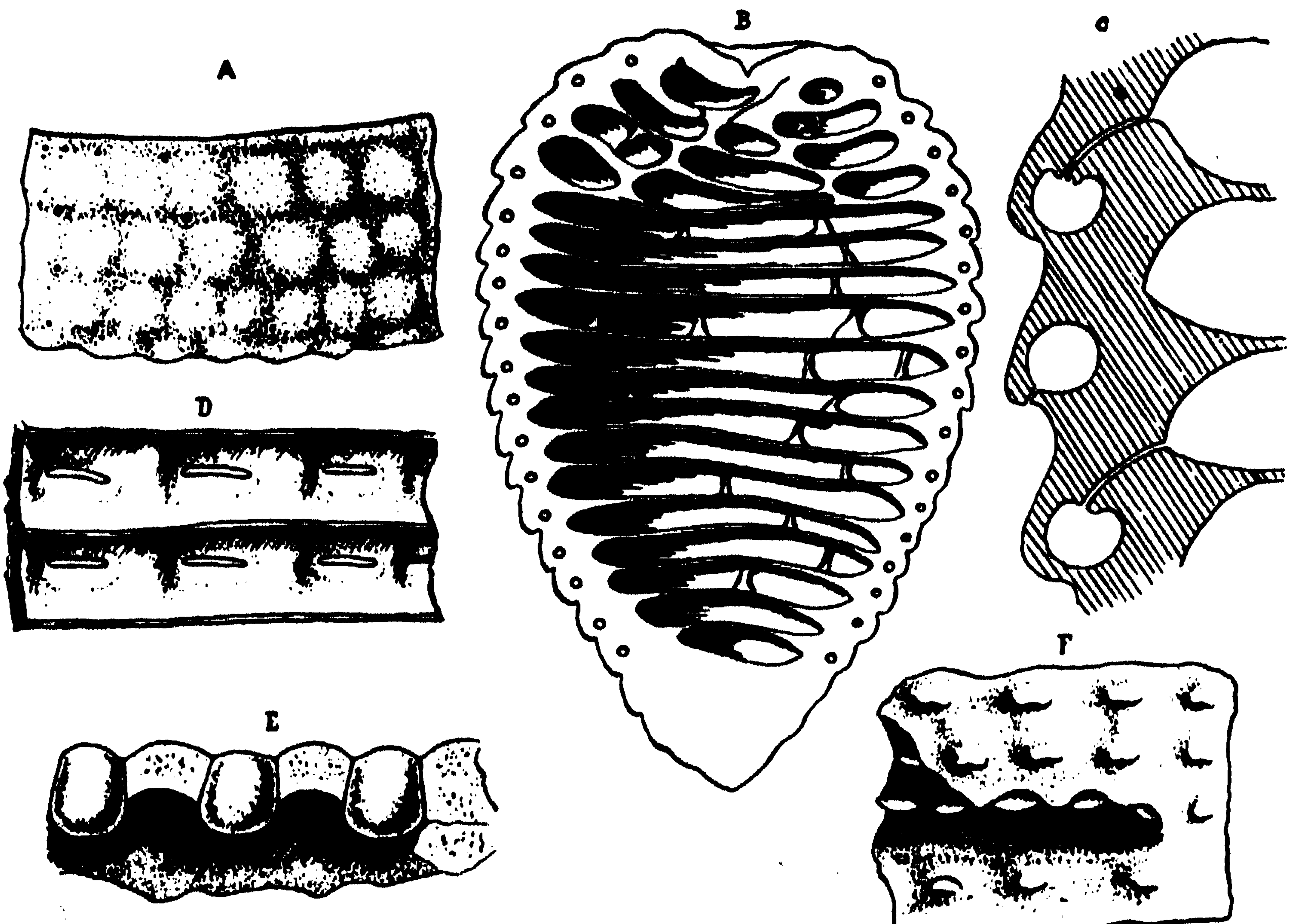


FIG. 3. ARCHITECTURALLY PERFECT SUBTERRANEAN NEST OF *Apicotermes* IN THE BELGIAN CONGO, WELL VENTILATED AND SHINGLED TO SHED WATER. (*a*) PORTION OF EXTERIOR TO SHOW PORES AND MAMMILATE SWELLINGS. (*b*) TRANSVERSE SECTION OF ENTIRE NEST. (*c*) VERTICAL SECTION OF PORTION OF NEST. (AFTER HEGH.)

The chief food of termites is cellulose, which they obtain from both living and dead vegetation; termites are among the few forest insects that attack both living and dead forest trees. In the intestines of most termites are a living fauna and flora of great diversity present in enormous numbers. Protozoa (Flagellates), Amoebae, Spirochaetes and fungi occur. These odd-shaped protozoa contain enzymes which digest the cellulose of wood for the termites; without the protozoa the termites can not live. The rôle of the Amoebae, Spirochaetes, etc., in the intestines of termites is not as well known.

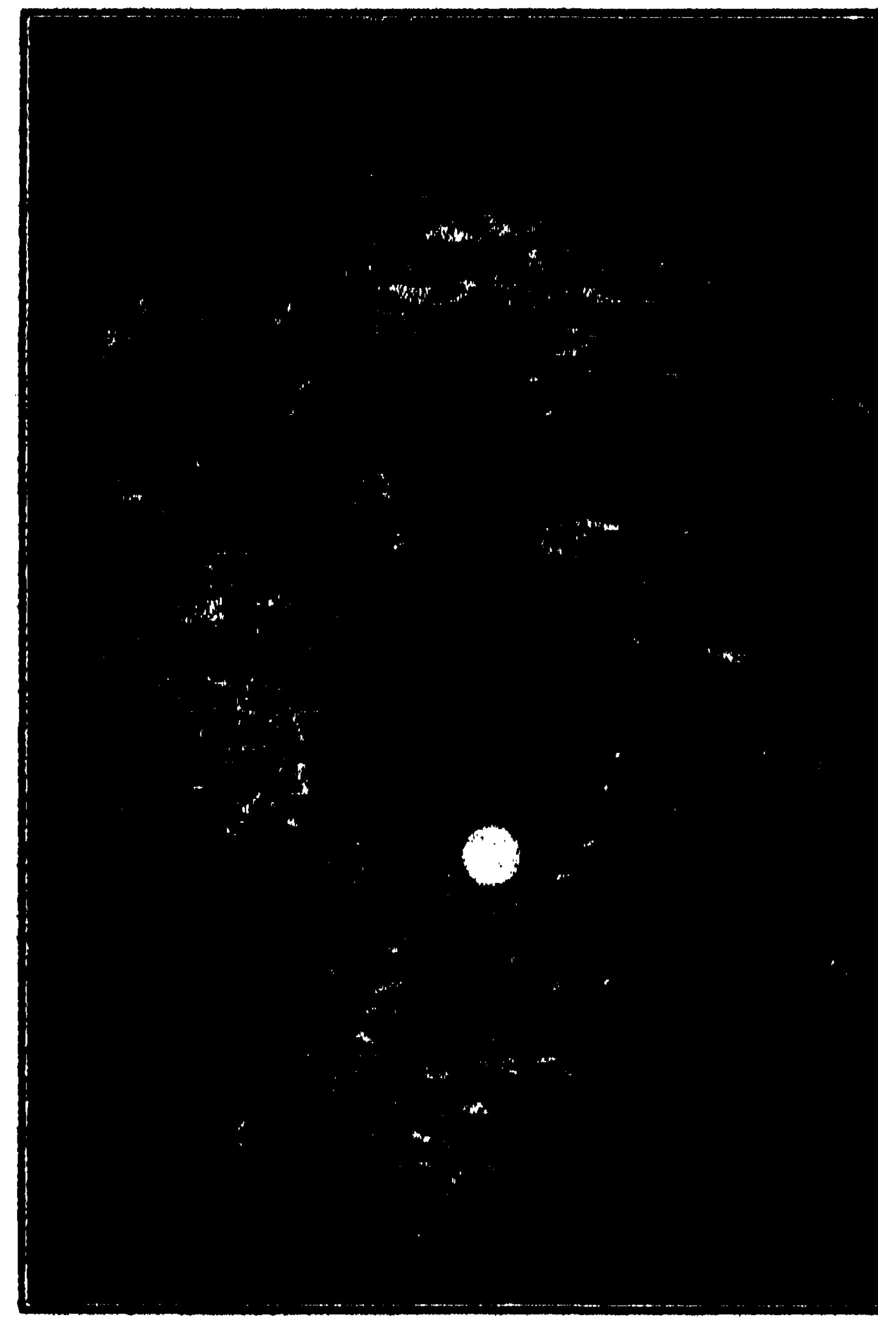
With the clearing of forest land and increasing cultivation of the fields termites or white ants have become increasingly destructive to the buildings and crops of man. The balance of nature has been upset by the destruction of the breeding places of termites in the forest and sodded soil. Greater building operations by man, especially speculative building, has been another factor in the increase of termite damage to buildings.

Owing to lack of information on the destructiveness of our forty-two species of termites or white ants, and their wide distribution throughout the United States, buildings are often improperly constructed and erected with untreated woodwork directly in contact with the ground, leaving the way open for the entrance of subterranean termites.

In consequence of such improper construction, termites burrow into the wood and may greatly damage the woodwork of the building before their presence is detected. It is a great hardship for a man on a moderate salary to make a large initial outlay on a new house and,

after one or two years, be forced to expend several hundred dollars additional to reconstruct the building to eliminate termites. The cost of repairing termite damage to buildings and preventing further attack averages from $500 to $2,000, but in some cases is as high as $10,000 to $25,000. Often the expenditure of a few hundred dollars additional during the construction of a building to render it termite proof would save thousands later necessary for repairs.

FIG. 4. EXTERIOR OF ENTIRE NEST SHOWN IN FIGURE 3.



—*Photograph by J. Zetek*

FIG. 5. LOW TURRET-LIKE NEST OF TERMITES (*Microcerotermes*) IN PANAMA. (THE WHITE DISK IS A WATCH.)

TERMITES IN THE UNITED STATES

Despite popular opinion, practically all the termite damage in the United States is done by native species and such serious damage occurs throughout eastern United States, the Gulf States, Southwest, the Central West and the Pacific Coast. Damage by termites in the "corn belt" is almost as serious as in some of the southern states. Such damage by termites occurs not only in cities but also in rural regions.

Termites of two distinct types occur in this country. Those subterranean in habit burrow through the soil and only

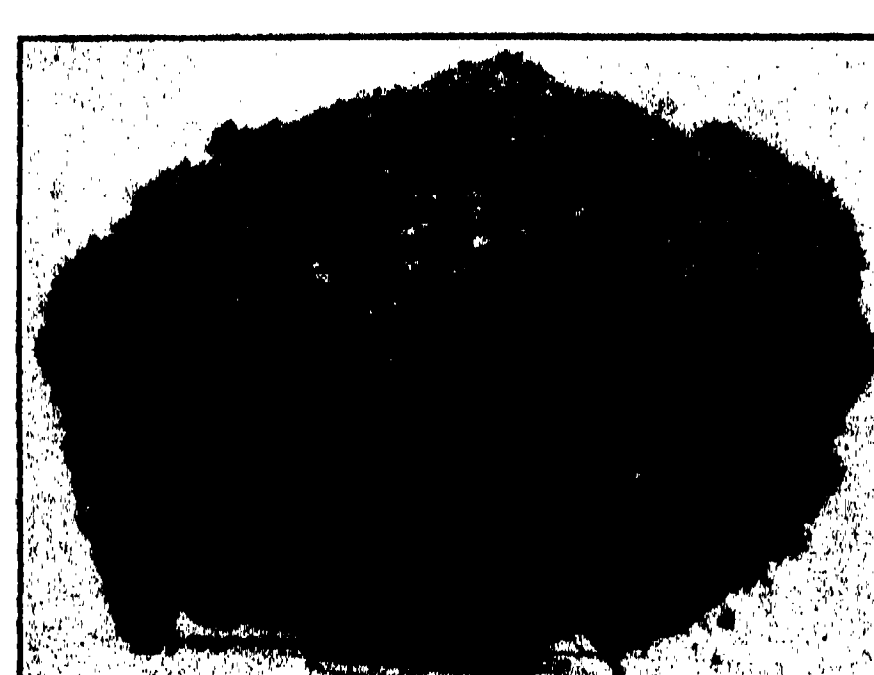
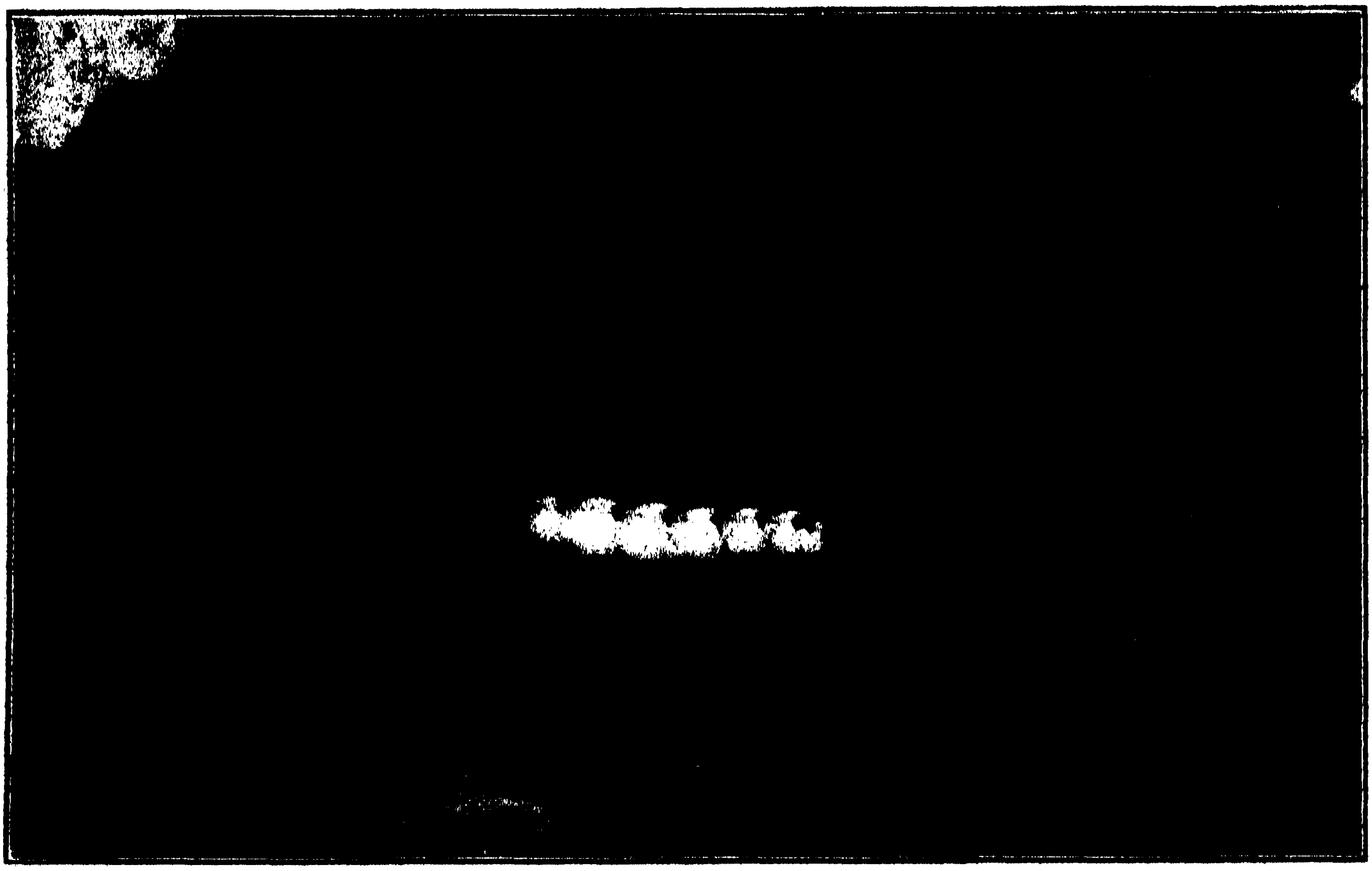


FIG. 6. EARTH-LIKE CARTON NEST ON GROUND OF *Armitermes chagresi* SNYDER. PANAMA.



—*Photograph by J. Zetek*

FIG. 7. ROYAL CELL WITH DEALATED, MACROPTEROUS QUEEN IN CELL OF THE SUBTERRANEAN TERMITE *Microcerotermes exiguus.*

attack wood indirectly from the earth, with which they must maintain contact, to obtain the moisture so necessary to their life (Figs. 9–12). Subterranean termites are widely distributed throughout the United States, over most of which they damage buildings.

Non-subterranean termites never burrow in the earth, but attack wood directly (Figs. 13, 14); they do not require much moisture and will survive in wood with less than the 10 per cent. moisture content of air-dried wood; small pellets of digested wood betray their presence (Fig. 15). These "powder-post" termites are not widely distributed and damage to buildings only occurs in that half-moon of country between a slack line drawn from Norfolk, Va., to San Francisco, Calif.

INSULATION AGAINST SUBTERRANEAN TERMITES

The only effective permanent preventive and remedy is the proper construction of the building with the knowledge of the habits of termites and the specific that will eliminate them. This specific against subterranean termites is "insulation" of all untreated woodwork from contact with the ground; it can be accomplished by the use of stone, concrete or brick foundations and lower flooring or the use of foundation timbers impregnated with coal-tar creosote and metal termite shields. The greatest portion of all termites which damage buildings in the United States is of subterranean habit; if they can be kept from reaching woodwork from the ground they can not survive in the building. Also, if present in a building, after all untreated wood, such as joists, wooden floors, sills, etc., has been removed from contact with the ground, they will die out, *i.e.*, dry up, even if the termites have penetrated to the height of several stories in the building. They have been cut off from their moisture supply in the ground, which is necessary for their life.

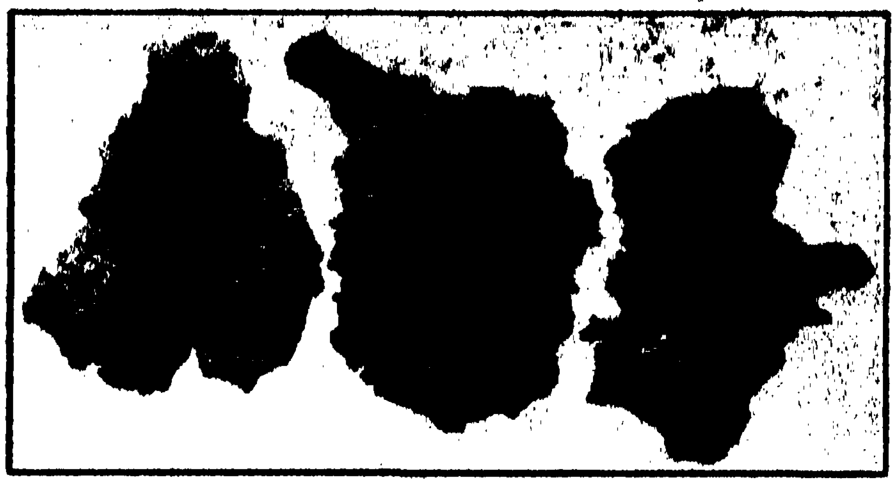


FIG. 8. TAR PAPER AND TAR COATING OF UNTREATED WOODEN TIMBERS LAID IN CONTACT WITH THE GROUND PENETRATED BY SUBTERRANEAN TERMITES.

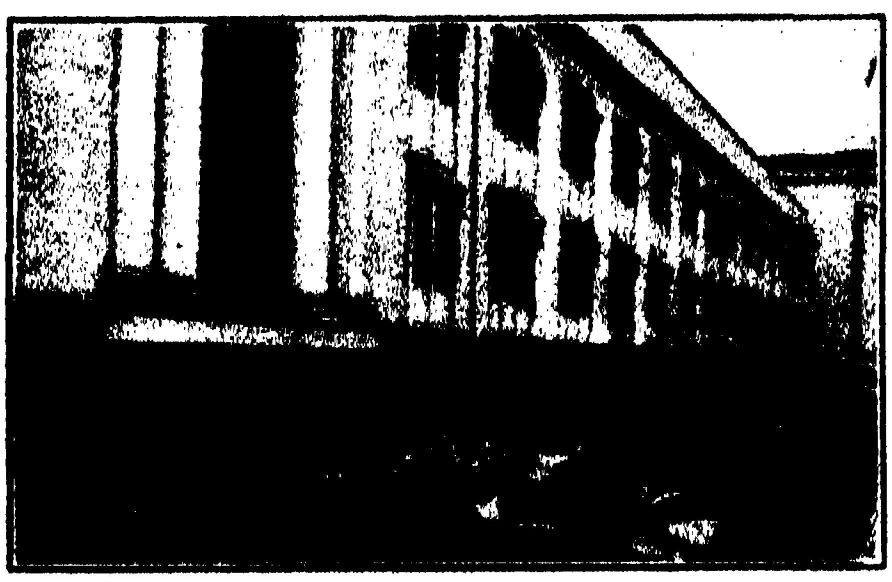


FIG. 9. TEMPORARY GOVERNMENT BUILDING AT WASHINGTON, D. C., THE FOUNDATIONS AND FLOORING OF WHICH WERE OF UNTREATED WOOD IN CONTACT WITH THE GROUND AND HENCE WERE BADLY DAMAGED BY SUBTERRANEAN TERMITES (*Reticulitermes flavipes* KOL.). IT WAS NECESSARY TO REPLACE THIS UNTREATED WOOD IN CONTACT WITH THE GROUND TO REMEDY THE TERMITE DAMAGE AND PREVENT FURTHER DAMAGE. DURING THE FISCAL YEAR 1926 SUCH REPAIR WORK, NECESSITATED BY TERMITE DAMAGE, COST $140,000 AT WASHINGTON, D. C.

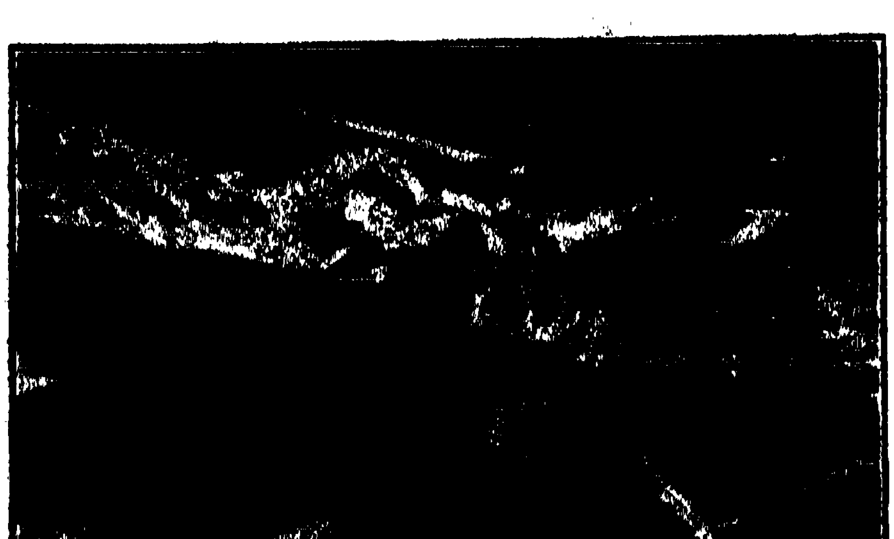


FIG. 10. A CLOSER VIEW OF THE DESTRUCTIVE ACTIVITIES OF THE TERMITES ON THE TIMBERS OF THE BUILDING SHOWN ABOVE.

IMPREGNATION OF WOODWORK AGAINST NON-SUBTERRANEAN TERMITES

Where termites that attack wood directly and not from the ground occur, as well as subterranean termites, it is suggested that only woodwork impregnated with preservatives be used for exterior and interior construction, unless it is impracticable to obtain such treated wood. Buildings should have the doors and windows screened to prevent entrance of the flying adults.

While impregnation with coal-tar creosote is the most effective treatment

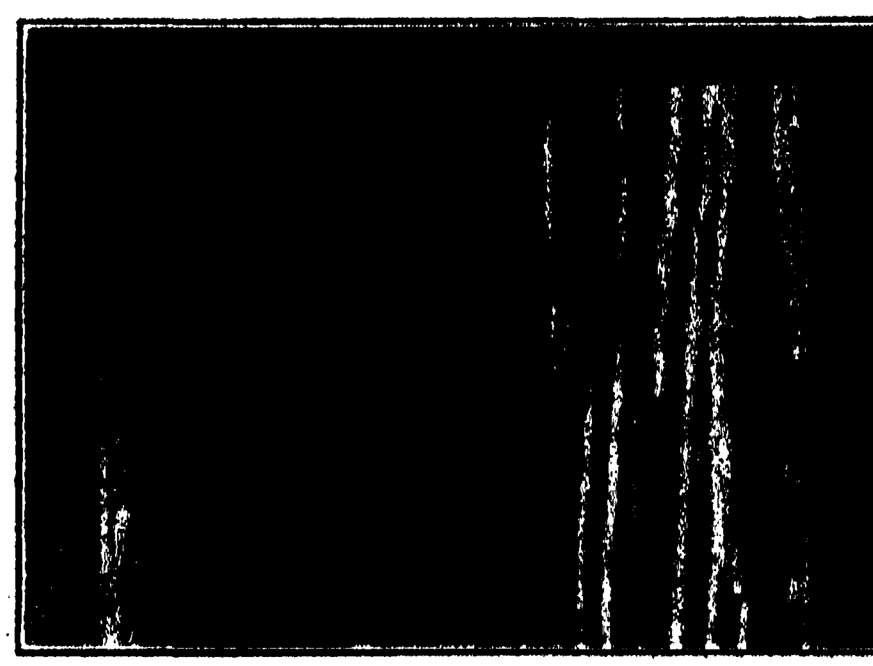


FIG. 11. OAK FLOORING DAMAGED BY TERMITES, UPPER SURFACE NOT PENETRATED, BUT INTERIOR HONEY-COMBED BY SUBTERRANEAN TERMITES (*Reticulitermes* SP.).

for foundation timbers to be set in contact with the ground, for interior woodwork and furniture, etc., not in contact with the ground impregnation with zinc chloride, etc., is recommended; wood so treated can be finished and painted.

BUILDING CODE MODIFICATION

In 1923 the first attempt was made to have building codes modified to prevent termite damage and this was made in Burlington, Iowa, where efforts were made to have no untreated wood placed in contact with the ground but that all such timber should be treated with coal-tar creosote.

Recently the Bureau of Entomology of the Department of Agriculture has

been widely advocating the slight modification of the building regulations of various cities so as to include simple rules to prevent attack by these insects. This educational propaganda addressed to city engineers has been conducted with the assistance of the National Lumber Manufacturers' Association, the United States Department of Commerce, Lumber Division of the Bureau of Foreign and Domestic Commerce, the American Wood Preservers' Association and the Associated Press. The National Wood Utilization Commission appointed

FIG. 12. UNDERWEAR DAMAGED BY SUBTERRANEAN TERMITES (*Reticulitermes* SP.) IN AN INFESTED BUILDING IN GEORGIA.

by President Coolidge, with Secretary Hoover as chairman, has an ant-proofing campaign on its program, which will receive early action.

Termite-proofing building campaigns have been advised in certain cities similar to that conducted by the Public Health Service in rat-proofing. Indeed rat-proofing, fire stops and the prevention of decay and insect damage can all be effected by similar methods.

In rural regions, where there are no building codes or chambers of commerce, the educational work can be conducted by prominent citizens with the help of county agricultural agents.

In Honolulu, Hawaii, a million dollars is the annual damage to buildings

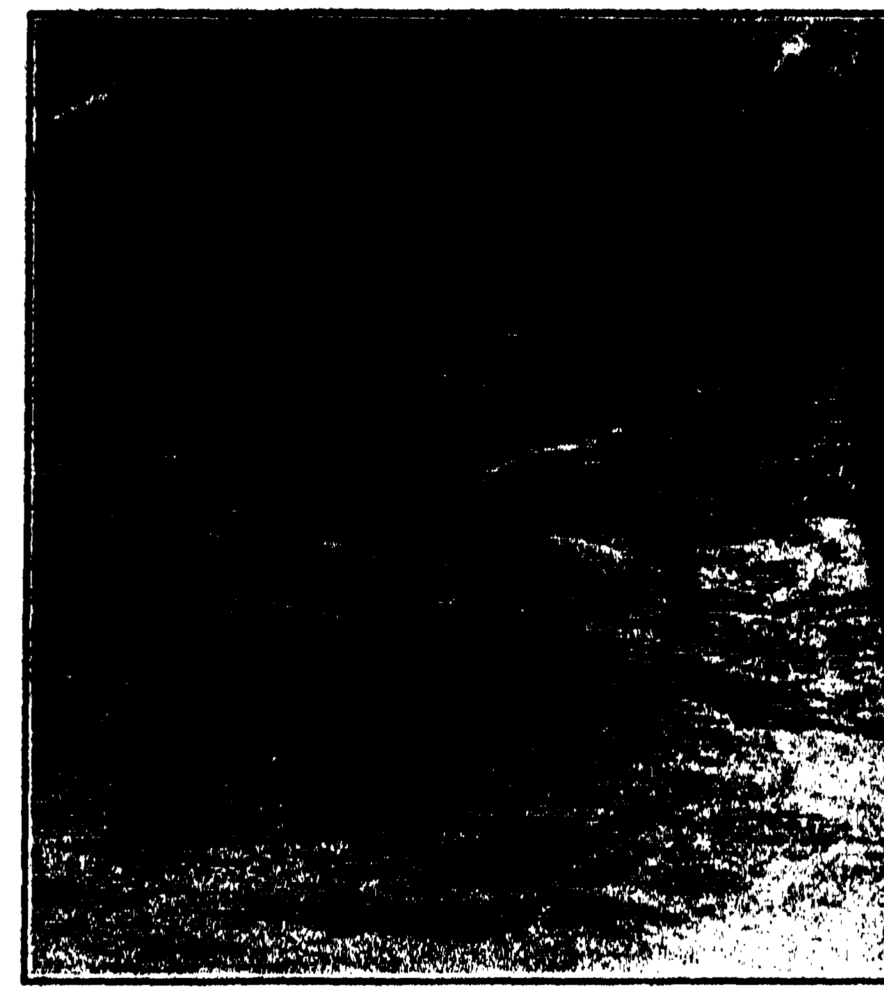


FIG. 13. ENTRANCE HOLES INTO WOOD OF NON-SUBTERRANEAN SPECIES OF *Kalotermes*. THESE ARE ABOUT THE SIZE OF BB SHOT AND APPEAR SIMILAR TO THE EXIT HOLES OF WINGED ADULTS OF SUBTERRANEAN SPECIES OF *Reticulitermes*. IN COTTONWOOD TIMBER IN ARIZONA.

done by termites; this city has recently advocated a building code containing fourteen points relating to termite control. Eighty per cent. of the frame buildings in New Orleans have been damaged by termites and 50 per cent. of the business buildings at Pasadena, Calif., some dangerously. Termites annually inflict a million dollars' damage to buildings in Illinois. At Washington, D. C., damage to government and privately owned buildings contin-

FIG. 14. UNTREATED WOODEN RAFTER IN BUILDING DAMAGED BY NON-SUBTERRANEAN TERMITES. THESE TERMITES ATTACK THE WOOD DIRECTLY AND DO NOT BURROW IN THE GROUND.

FIG. 15. IMPRESSED PELLETS OF POWDERED, PARTLY DIGESTED, EXCRETED WOOD OF NON-SUBTERRANEAN TERMITES; THESE PELLETS FALL FROM WOOD AND ARE AN INDICATION OF INFESTATION.

ues to be serious. Slightly modified building codes for the entire west coast, from Seattle to San Diego, have been considered by the Pacific Coast Building Officials Conference, of Long Beach, Calif. New Orleans has recently adopted termite-proofing measures in its building code. Similar serious damage occurs in southern Florida and in the southwestern states. The aim of the Bureau of Entomology is standardized modified building codes for all the regions where termite damage is serious.

HITS SMALL HOUSEHOLDER

While special effort has been made to protect the small householder from

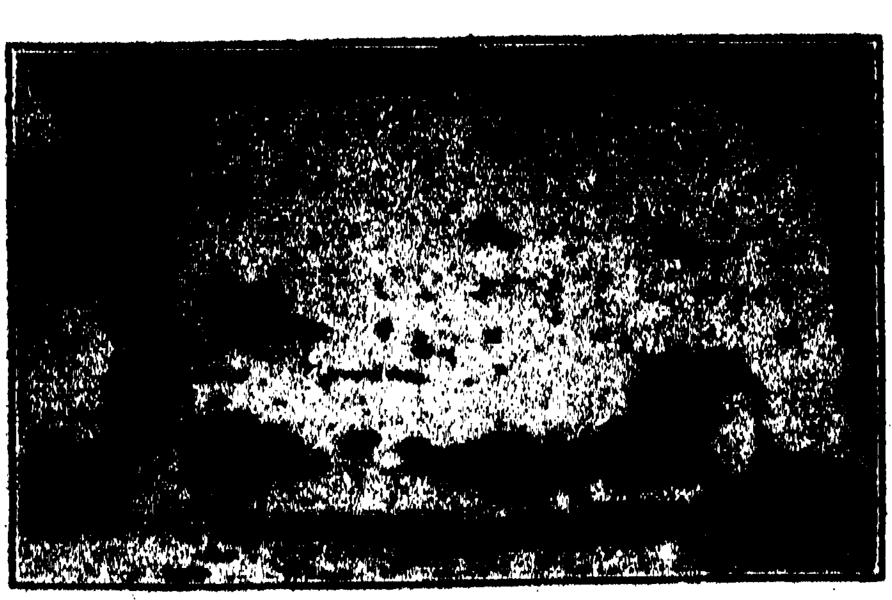


FIG. 16. SUBTERRANEAN TERMITES (*Reticulitermes flavipes* KOL.) PENETRATING LIME MORTAR IN BRICK FOUNDATION OF BUILDING AT WASHINGTON, D. C.

speculative and careless builders many of the more permanent modern buildings are improperly constructed. This applies to some of the government buildings in Washington. With the cooperation of the Superintendent of Public Buildings and Grounds much progress has been made in repairing such buildings and some such work has been done with temporary buildings where practicable.

The use of untreated wood in the foundation of buildings is a great waste of wood, and the replacement cost is often very much greater. A model demonstration termite-proof building has been erected in Canal Zone, Panama, by the American Wood Preservers' Asso-

FIG. 17. TESTS OF MORTARS AND CONCRETES AT FALLS CHURCH, VA., TO DETERMINE THE MOST SUITABLE MIXTURES AND METHODS TO PREVENT ENTRANCE BY SUBTERRANEAN TERMITES.

ciation and associated companies in consultation with the Bureau of Entomology to serve as an object lesson; other similar buildings are to be erected in the United States.

THE MODIFIED CODE

No foundation timbers, floors, sills, clapboard, etc., of untreated wood should be laid on or in the earth, and untreated beams must not be laid in concrete without at least one inch of concrete underneath and separating it from the earth. A special grade of hard mortar (Figs. 16, 17) should be used in making cement for foundations or in cellar walls where they are in contact with the earth, since termites are able to penetrate certain mortars after some

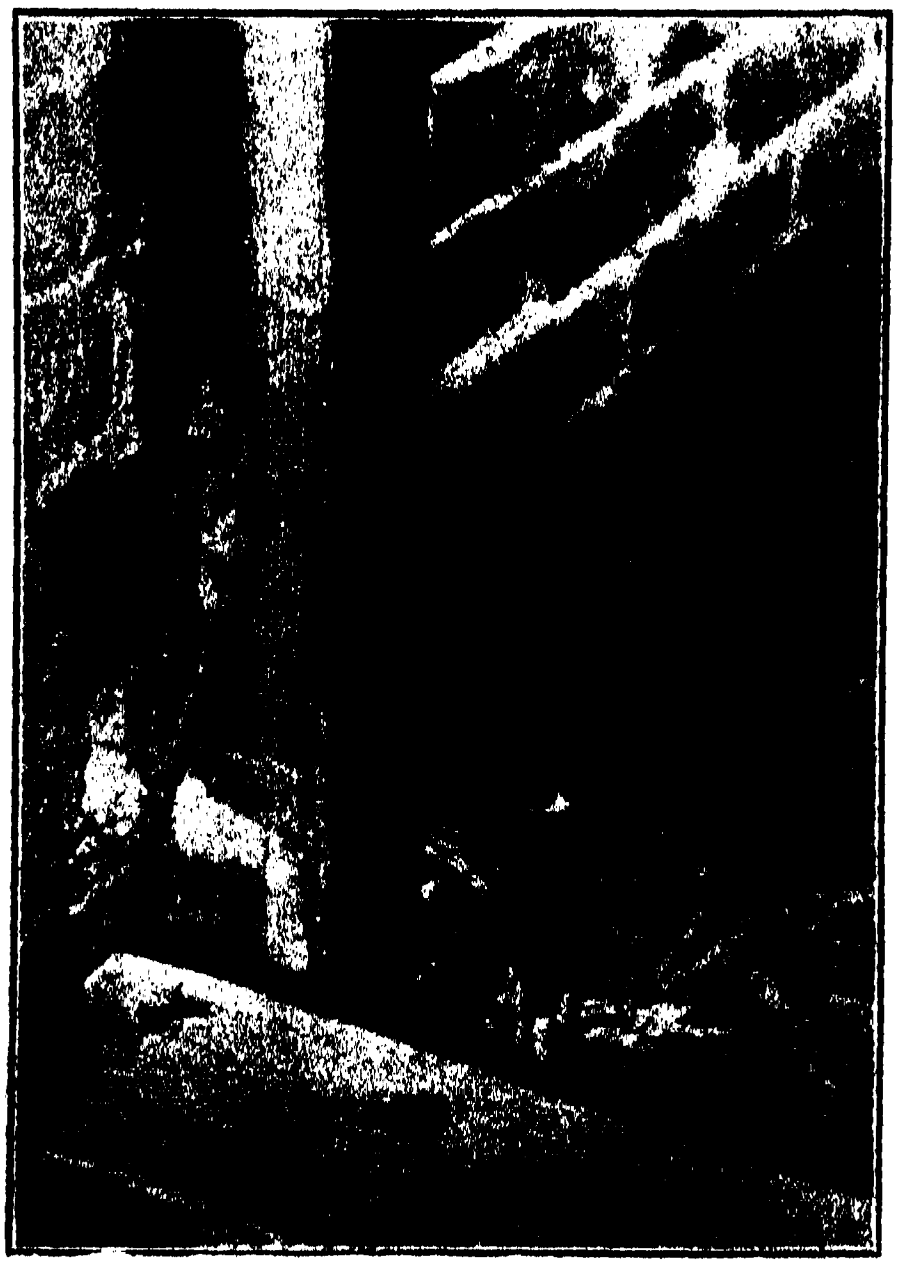
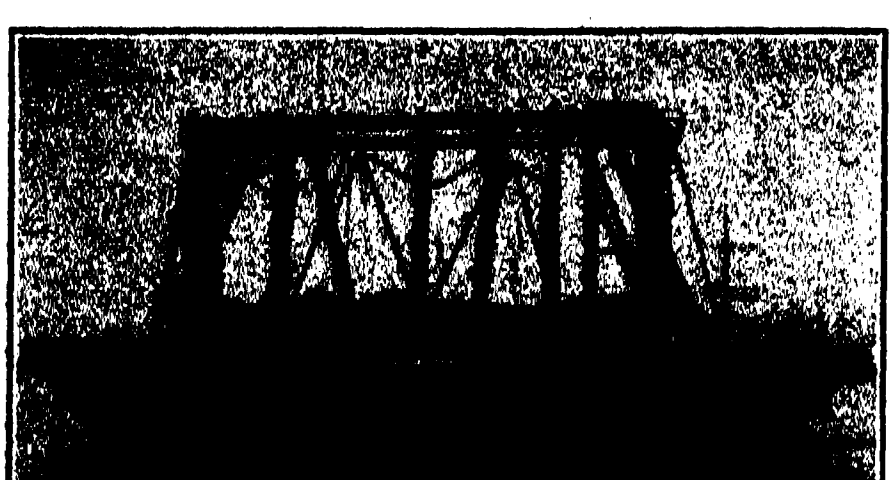


FIG. 18. EARTH-LIKE SHELTER TUBES CONSTRUCTED BY SUBTERRANEAN TERMITES (*Reticulitermes* SP.) FROM INFESTED FLOORING OVER UPRIGHT UNTREATED WOODEN TIMBERS AND BRICK WORK IN A BUILDING, SAN FRANCISCO, CALIF.



—*Photograph by Wm. McKay*

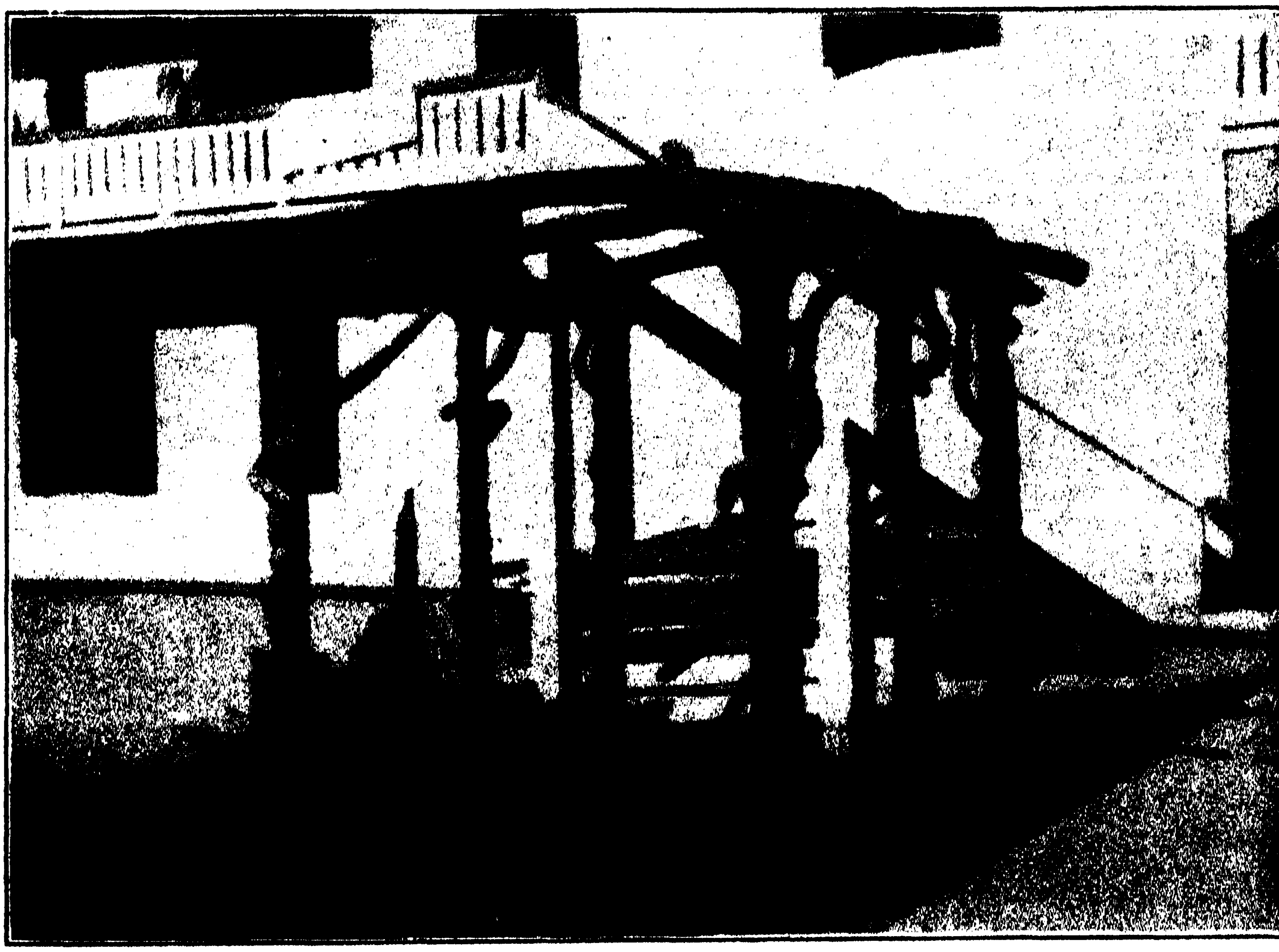
FIG. 19. COAL BARGE INFESTED BY SUBTERRANEAN TERMITES IN THE HARBOR AT HONOLULU, HAWAII. SOME DIRT WAS LODGED ALONG THE BOTTOM, BUT MUCH MOISTURE WAS PRESENT. PROBABLY THE INFESTATION OCCURRED BY WINGED ADULTS FLYING TO THIS BOAT. SUCH A BOAT WOULD BE A SOURCE OF DANGER AT PORTS OF CALL WHEN THESE FLYING ADULTS WOULD EMERGE FROM THE WOOD AND SPREAD THE TERMITE. INCIDENTALLY THIS TERMITE (*Coptotermes* SP.) WAS INTRODUCED FROM FORMOSA, JAPAN. REPAIRS COST $5,000.

years' service. For greater safety all brick work extending below the surface of the ground should be faced and capped with concrete at least one inch thick. Metal termite guards should be provided between the earth and treated foundation timbers, stone, brick or concrete foundations. Termites construct over impenetrable substances earth-like shelter tubes (Fig. 18) of small diameter, through which they travel to reach untreated wood. In consequence they can be kept out of buildings by means

FIG. 20. HEALTHY LIVING SUGAR-CANE KILLED BY SUBTERRANEAN TERMITES (*Reticulitermes* SP.) IN EXPERIMENTAL GREENHOUSE IN VIRGINIA.

of metal barriers. By simply inserting a sheet of galvanized iron, zinc or copper or "termite shield" into the masonry and turning the projecting edges downward at an angle, communication of termites with the earth, where they obtain moisture, can be cut off. In less pretentious frame buildings, metal caps are placed over the tops of construction stone piling or pillars, or wooden supports.

This is a similar method to that used in rat-proofing corn cribs. It is effec-



—*Photograph by G. N. Wolcott*

FIG. 21. THE TERMITE IN ART. AN ARTIFICIAL CARTON TERMITE NEST OF CONCRETE ON CONCRETE ARBOR IN PORTO RICO.

tive and practicable where untreated timber is placed over masonry foundations. These shields need not be unsightly but can be made decorative.

These slight modifications of the building regulations of cities by city engineers would save much property as well as the time and worry to householders. It is a form of house insurance. A prospective home builder should insist on obtaining this safeguard. It will pay in the end.

There are three principal points—insulation of untreated woodwork from the earth, metal termite shields to shut off the shelter tubes and treatment of interior woodwork and furniture with preservatives. The latter recommendation is only essential in the Gulf States, Southwest and southern California

FRESH-WATER SPONGES IN WINTER

By Dr. ANN H. MORGAN

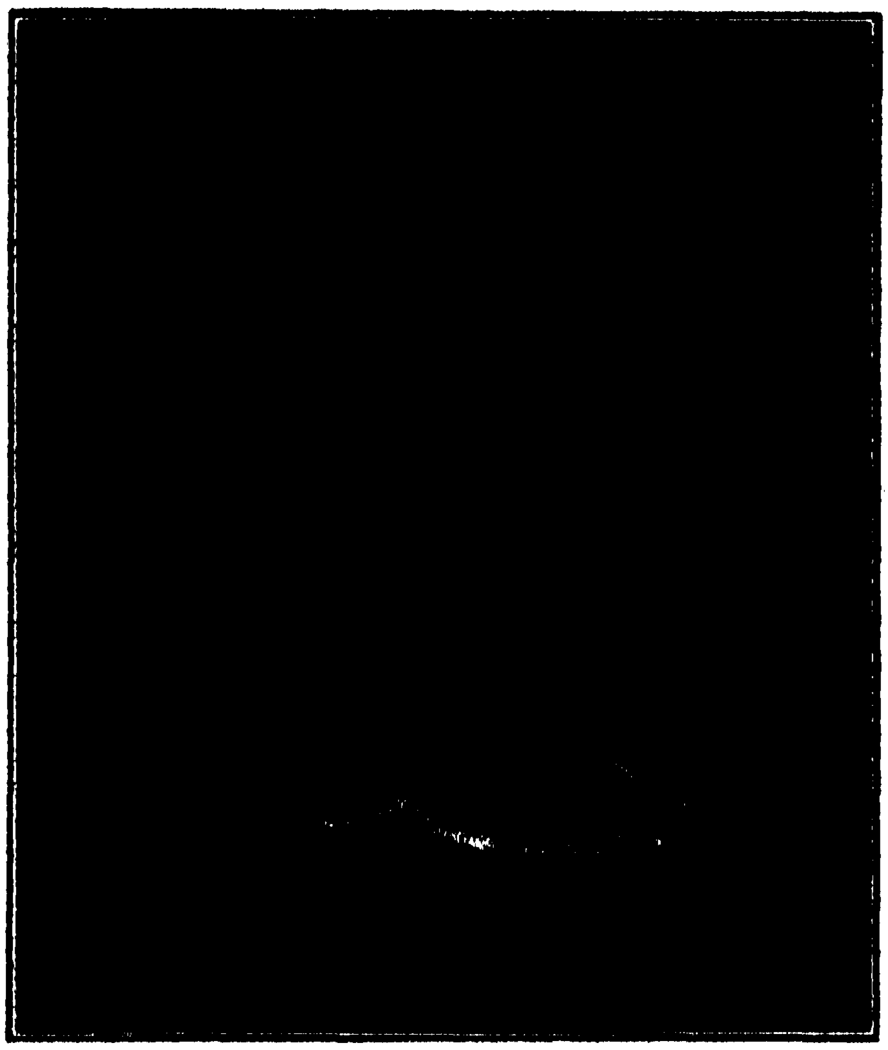
MOUNT HOLYOKE COLLEGE

THERE were nearly twenty animals on one stone—caddis worms, mayflies, water pennies, planarians, Bryozoans and sponges; they were creeping and sprawling, clinging or stuck fast, each according to its kind. Yet it was in the middle of January and the stone had been pulled through a hole in ice which was two inches thick. Even in a shallow brook like that things were far from frozen, and although one animal population had dug down into the bottom, another had stayed up in the water swimming and clambering after food, making nets and waiting for their catch. Most of these were young animals whose rapid growth would begin in February when the early spring food supply became abundant in the brooks. This community in winter resembled a similar one in spring, the bronze copper pennies looked like themselves, only smaller, and the Mayflies were unmistakably like those of April and May. But the winter sponges hinted nothing of their animal relations. They were like so many fig-seeds held to the stone in a bed of bristles. The bristles were the spicules, the skeleton remains of its summer colony, and the seed-like spheres were the gemmules or winter buds of the sponge. Gemmules are little balls of sponge cells, literally samples of sponge, which can grow into a complete colony when there is a proper stimulus from the warm water of spring.

Gemmules may look nothing like sponges, but they will do so speedily if they are given a chance. Those which are shown in these photographs were taken from a shallow brook completely frozen over, in January. They were crowded among the spicules holding them to the stones, and no better picture of clustered fig-seeds could have been wanted. But a lens revealed their

THESE ARE LIVING ANIMALS

FRESH-WATER SPONGES IN WINTER. MAGNIFIED TWELVE TIMES.

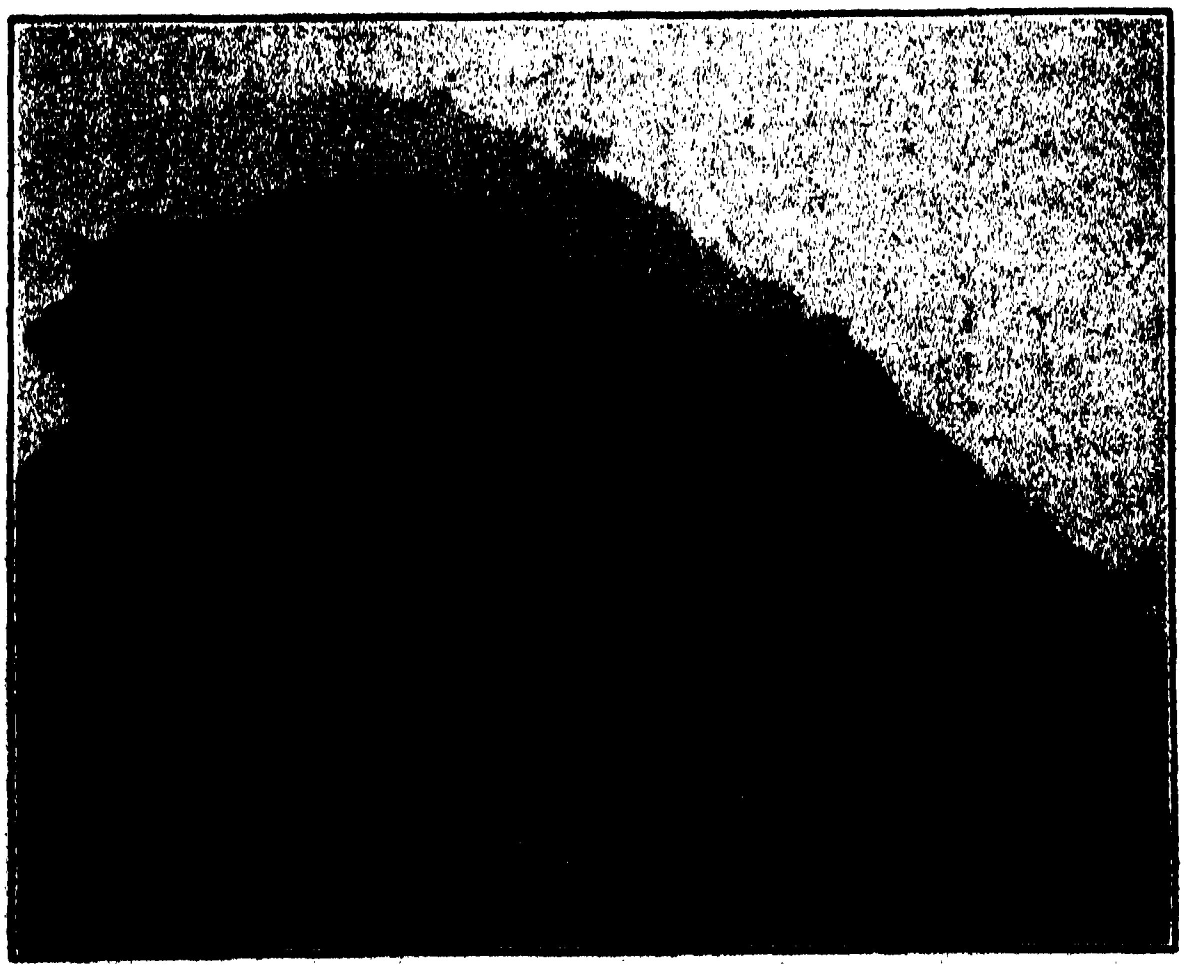


COLONIES GROWING ON GLASS IN JANUARY

THE DARK BODIES ARE THE GEMMULES FROM WHICH THEY HAVE GROWN. MAGNIFIED TWELVE TIMES.

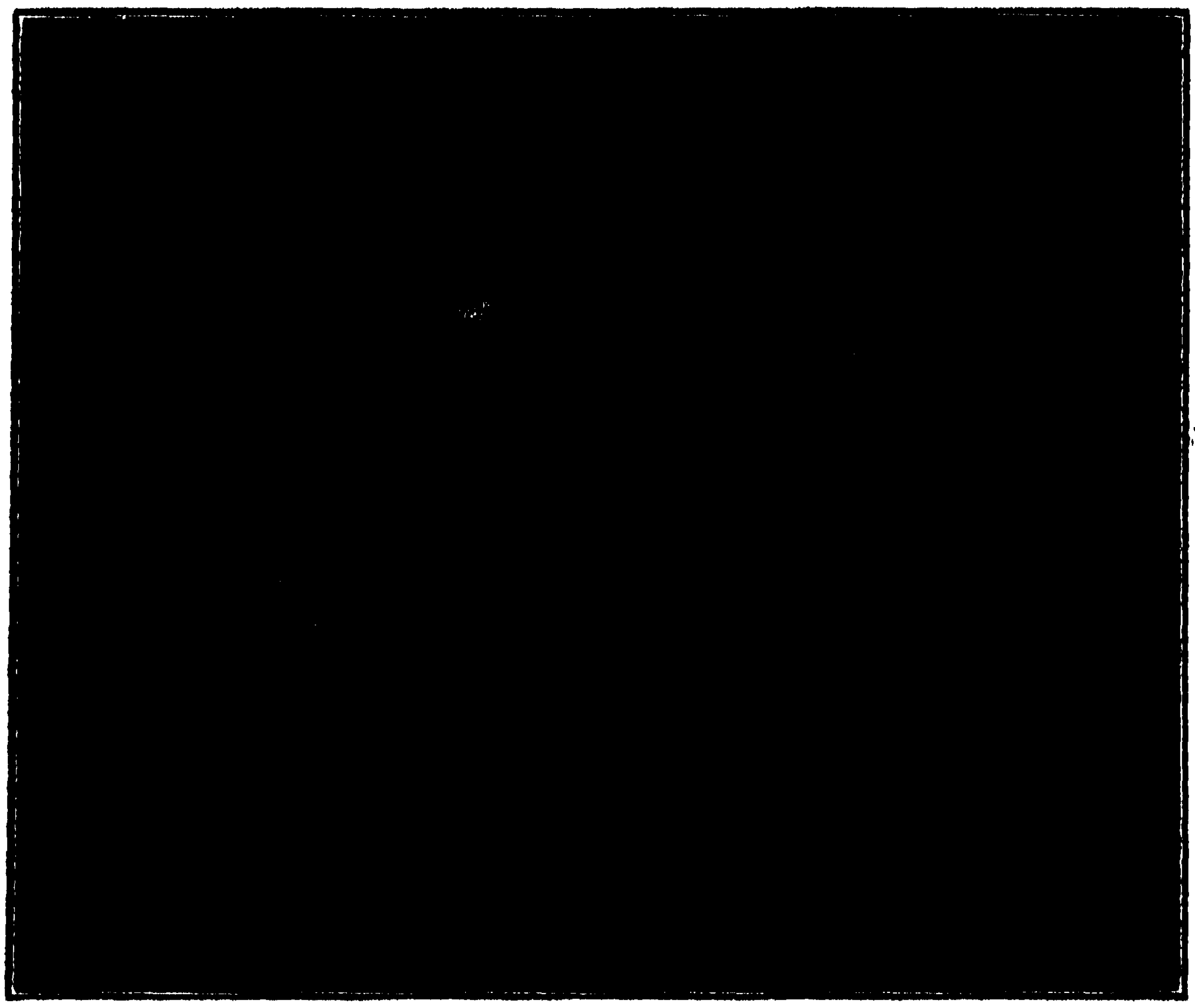
spicule-covered shells with the one small hole in each quite invisible to the naked eye. Some of them were scraped from the rock, taken into the house and put into a dish of water which was set near the window, but outside the path of direct sunlight. Pieces of clean glass were put into the dish, and as the gemmules were dropped down upon them they fell a little distance apart as they are shown in these pictures. For the first few hours they would roll about at the slightest jar of the dish, but within a day or two they had stuck fast. The water was kept fresh and moderately cool, and in three days white plugs were just visible at the holes in the shells which by now had begun to swell and crack open. In another day sponge cells had come through all the crevices and creamy white streams of them had grown down onto the surface of the glass and surrounded the emptying husk of the gemmule.

Five days after the gemmules had been dropped on the glass each hollow shell lay in the midst of a small but flourishing sponge colony with thousands of cells, with true sponge osteoles and gastral cavities. Within a couple of days the transparent borders of the colonies had spread over the surface of the glass and run together so that the gemmule shells were the only signs left of the separate colonies. Several chimney-like pipes had grown upward and had osteoles at their tops, while shorter sacs



SPONGE COLONY

GROWING UPON A STONE IN SUMMER. NATURAL SIZE.



SEVEN DAYS AFTER THE SEED-LIKE GEMMULES WERE TAKEN FROM THE BROOK

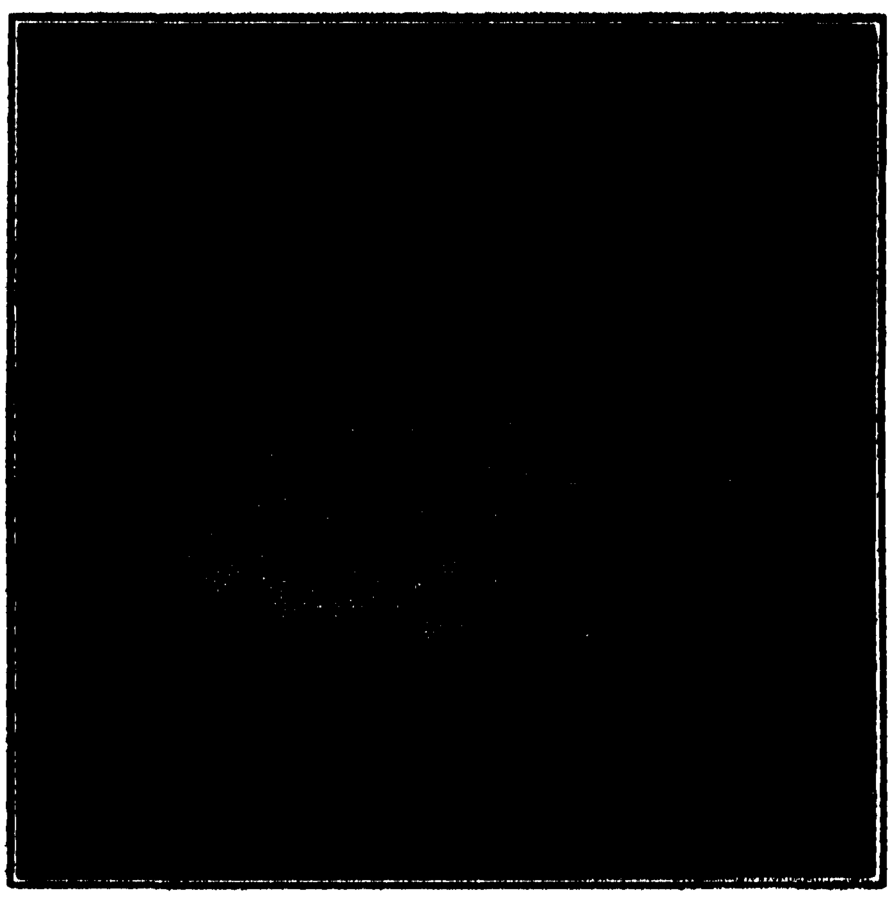
MAGNIFIED TWELVE TIMES.

were stretched thin at their swollen knob-like ends but did not yet have any openings there. Canals and chambers forming beneath the surface began to show as transparent streaks and spots and finally the glass-like spicules began to appear in clusters, visible through a hand lens along the transparent border of the colony. When carmine, a very fine red powder, was scattered lightly over the colony it rested on the surface only a very short time before a few particles of it, probably the very finest, came out on the gentle currents of water which were issuing from every osteole. This too could be seen with a hand lens and was enough to show that the little patch of cells was already carrying on the activities of a sponge. Although it was still smaller than the head of a carpet tack and had been growing outside the gemmule shell for only six days it now both looked and behaved like a sponge colony.

In order to understand either the anatomy or the activities of sponges it would be necessary to study young and full-grown colonies very carefully. Mature fresh-water sponges, such as the common Spongillas, are low cushions of cells whose surfaces are pierced with thousands of minute pores, and with hundreds of larger holes, the osteoles, mounted upon little peaks above the surface level. The pores lead into cavities, the already mentioned chambers first showing as transparent streaks in the sponge. Water is drawn into these so-called dermal chambers and on through minute incurrent canals which carry it into still another series of very small and numerous chambers out of which it passes by other small channels, the excurrent canals. These converge into the gastral chamber from which it is finally passed by way of the osteole to the outside. It was these currents of water from the osteoles that brought the particles of carmine carried through all of these passages after it had been scattered upon the surface of the young colony. Thus water carrying the food and oxygen supply passes in a steady current, as long as the sponge lives, through the pores to the dermal chambers, on through the incurrent canals and the adjoining small chambers through the excurrent canals and into the gastral

chamber to its final exit by way of the osteole.

In summer sponges are much more conspicuous than in winter, but they do nothing which is so spectacular as this burst of growth in the new colony. Fresh-water sponges grow in many lakes and brooks, beneath lily pads, on the undersides of floating sticks and over the stones of brook beds. If the water is muddy or carries a load of dropping particles, their pores become clogged and they are starved and smothered, but clear water bears oxygen to them and



BEGINNINGS OF THE SKELETON

NEEDLE-LIKE SPICULES OF HYDROUS SILICA (OPAL) ON THE EDGE OF THE COLONY. MAGNIFIED TWELVE TIMES.

a sufficient food supply, either dissolved or of microscopic plants and animals. Sponges flourish under these conditions and are abundant in many waters.

Colonies of Spongilla and other common fresh-water sponges often measure several inches in extent, while still others form clumps as large as a quart measure. The Spongillas which grow in direct sunshine are soft green or even brilliant green with chlorophyll, but individuals of the same species hidden beneath rocks or even shaded by brook banks are straw colored or creamy white. The pale ones are more easily recognized as sponges; they are the color of the dried or bleached ones which we are used to seeing; their surfaces are full of holes like bath sponges; they will squeeze dry in the same way and will give off the sulphury smell suggestive of a salt-water sulphur-sponge.

The Spongillas harbor some constant but very inconspicuous visitors, larvae of Spongilla flies which later emerge into the air as four-winged flies. These immature Spongilla flies have long antennae and six legs which readily identify them as insects. They are small, never more than a quarter of an inch long. They are yellowish green with faint dapplings of brown on their backs and with little bristles sticking out from their bodies. Bits of debris and broken sponge catch upon these bristles and hide the shape of their bodies. Being hidden in all these ways they also eat the sponge tissue; they fill their food canals full of it and so become literally sponge colored inside as well as outside. No one could want a more convincing camouflage than a young Spongilla fly which has eaten its way down into a sponge. It may be resting there with its whole length in full view, but be quite invisible even to careful scrutiny through a lens. It is only when it clambers over the sponge that it may be caught, and even then it is much more like a piece of sponge on legs than like an insect.

In early fall the Spongilla colonies, like the rest of the fresh-water sponges, begin to shrink and shrivel away. By October and November many of the cells have died and the spicules are left bare. But other cells have been drawn together in closely packed balls and have secreted a protecting crust about themselves. They have become the gemmules or the winter buds. These gemmules are the winter representatives of fresh-water sponges, and are seed-like in their looks and behavior; like seeds they can endure hard weather, but are so sensitive to changes that they will start to grow with any encouragement from warmth and fresh water.

CLIMATOLOGY AND SOME OF ITS APPLICATIONS[1]

By Professor ROBERT DeC. WARD

HARVARD UNIVERSITY

MEANING AND SCOPE OF CLIMATOLOGY

THE word *Klima* (derived from Κλινειν, to slope or incline) as used by the Greeks, doubtless originally had reference to the angle of the sun's rays. It was, at first, simply a mathematical or an astronomical term, not associated with any idea of physical climate as we use the word to-day. An excellent illustration of the ancient meaning of *Klima* is found in the system of *climates* proposed by the famous geographer, Ptolemy. This was a division of the earth's surface between equator and north pole into a series of *Klimata,* or parallel zones, separated by latitude circles and differing from one another simply in the length of the longest day. A change of one's *Klima* in those days simply meant a change of latitude. Such a change of position on the earth's surface was, however, gradually seen to mean a change in atmospheric condition as well as in the length of day. Thus *Klima* came to have its present meaning. Even in their own country with its rugged topography the Greeks surely observed in very early times that southern slopes or exposures have certain climatic advantages over northern slopes. The conception of *Klima* as merely indicating the inclination of the sun's rays must therefore inevitably soon have been given up in favor of the larger definition. *Climate,* as we now use the term, is the sum-total of the weather phenomena that characterize the average condition of the atmosphere at any place on the earth's surface. What we call *weather* is merely one phase in the succession of phenomena whose complete cycle, recurring with greater or less uniformity year by year, makes up the climate of any locality. Weather changes; climate does not. *Climate,* then, is average *weather.* It is the sum-total of all the weather. Climatology is the study or science of climates.

There is much misuse of the terms weather and climate. To illustrate, we can say, "The weather in Boston was rainy in May, 1928," or "The weather was cool in the early part of June, 1928." We can also correctly say that the "winter climate of New England is cold and snowy," although January, 1928, may have been relatively warm and "open." It is, however, incorrect to say, "The *climate* of Boston was cool and rainy in May, 1928." As soon as we speak of the atmospheric conditions of a single period of time, we must use the word *weather.*

RELATIONS OF METEOROLOGY AND CLIMATOLOGY

Meteorology and climatology are interdependent. It is impossible to distinguish sharply between them. Each needs the results obtained by the other. Meteorology is the more comprehensive term. It is the science of the whole atmosphere. Meaning, literally, the discussion or description of things suspended, or supra-terrestrial, it originally, as in Aristotle's first treatise on meteorology, included within its field not only the atmospheric conditions to-

[1] Introductory lecture in a course on "Man and his Climate," given before the Lowell Institute, Boston, November 19, 1928.

day associated with that science, but also stars, comets, meteors, earthquakes, auroras, the composition of matter and other subjects as well. In a strict sense meteorology now deals with the physics of the atmosphere. The study of meteors, except very indirectly, does not fall within its field. Meteorology considers the various atmospheric phenomena individually, and seeks to determine their physical causes and relations. Its view is largely theoretical, yet one of its main aims is to be of service to man. The aspect of meteorology of the most immediate, practical, everyday importance to man is that which concerns weather forecasting. In the synoptic daily weather map the unit of time is the essential thing, the observations on which the map is based all being made at the same time.

When the term meteorology is used in its broadest sense, climatology is a subdivision of meteorology. Climatology is largely descriptive. It aims to give as vivid a picture as possible of the interaction of the various atmospheric phenomena at any place on the earth's surface. Its unit is therefore place, while, as just stated, time is the fundamental unit in meteorology. The business of the weather forecaster is to predict tomorrow's weather, as well as he can in the light of our present knowledge. The climatologist, on the other hand, tells us in terms of averages what the general or normal atmospheric conditions in any locality are likely to be at any season or in any month, as inferred from past experience. This is in no sense a long-range forecast. It is simply a picture of what, under normal conditions, may reasonably be expected. Climatology rests upon physics and geography, the latter being a very prominent factor. Climatology may perhaps well be defined as geographical meteorology. Its main object is to be of practical service to man. Its method of treatment lays most emphasis upon the elements that are of most importance to life. Climate and crops; climate and industry; climate and health, are subjects of vital interest to man. Few sciences concern man more intimately in his daily life. It is immediately practical, of vital interest, and intensely human in all its applications.

Climatology Rests Upon Meteorological Data

Scientific climatology is based upon numerical results obtained by systematic, accurate and long-continued meteorological observations. It deals with the same groups of atmospheric conditions as those with which meteorology is concerned, viz., temperature, moisture, wind, pressure, evaporation, and so on. The characteristics of each of these so-called *climatic elements* are set forth in a standard series of numerical values, based on the day-by-day meteorological observations, corrected and compared by well-known methods. The official meteorological services all over the world give a large part of their time to the collection of climatic statistics, a function universally recognized as of equal importance with the daily weather forecasts. These statistics are indispensable in medicine, in biology, in engineering, in agriculture, in transportation and in many other branches of science and industry. Every person who carefully records an extended series of accurate meteorological observations potentially contributes to a better knowledge of the climatology of his country. American climatology really owes its beginnings to the pioneers who, alone and with inadequate facilities and equipment, faithfully kept their daily records in the earlier years of our country's history. Names that may well be remembered are those of the Reverend John Campanius, who in 1644–45, at the Swedes' Fort, near Wilmington, Delaware, kept what

is believed to be the first regular record of the weather on the North American continent; of the Honorable Paul Dudley, Chief Justice of Massachusetts, who kept a meteorological record at Boston in 1729–30; of Dr. John Lining, who began thermometer records at Charleston, South Carolina, in 1730 and maintained a more extended series of observations from 1738 to 1750; of Professor John Winthrop, of Harvard College, who from 1742 to 1778 kept regular weather records at Cambridge. It is not irrelevant to mention that Thomas Jefferson at Monticello and James Madison at Williamsburgh, Virginia, made "a series of contemporaneous observations" during the period 1772–77, which "showed that the climatic peculiarities of those two places harmonize completely."

It is the responsibility of the meteorologist to take the regular daily routine observations upon which, eventually, the structure of climatology is built. Every day, year in and year out, all over the world, on land and at sea, thousands of meteorological observers are patiently reading their instruments and recording their data for the future use of their fellow-men. As another has well expressed it, "the meteorologist's business is to make the bricks as perfect as he may, whatever the use to which they may be put. The climatologist, the biologist, the geographer, are the builders who must have sense and knowledge to use them."

Climatology a Science of the Future

So far as extreme accuracy of its data is concerned, climatology is inevitably to a considerable extent a science of the future, for the longer the series of observations, the more accurate are the results. Climatic tabulations necessarily quickly go out of date. Each year, each month, indeed each day, produces additional observations and thereby brings the averages closer and closer to the desired degree of accuracy. It is, therefore, with a relatively young science that we are here dealing. Climatology will grow as additional data accumulate concerning the atmospheric conditions in all parts of the world, and especially as observers in the thinly-settled and backward districts increase in number. It is a rather discouraging sentence which one of my English colleagues wrote a few months ago: "We shall never accurately know the distribution of the annual means of the meteorological elements over the world." In a sense this is, of course, true. But the degree of our discouragement with this situation will depend entirely upon our interpretation of the word "accurately" in the statement which I have just quoted. Absolute perfection of accuracy we can not hope to attain within any period of time that has any real interest to those of us who are living to-day. But accuracy sufficiently great to make our present knowledge of the world's climates of immense and immediate practical importance to man we have already attained. Is not the object of attaining ever-increasing accuracy the real inspiration and incentive of all our pursuit of knowledge?

In the fact that climatology is so young a branch of science we may, I believe, find the explanation of its rather scanty *general* literature. Its students have been so busy collecting and summarizing observations that there has been little time left over for the discussion of general principles and laws.

Summarizing Climatological Observations

Climate concerns first of all the *average* conditions. But *means* may be made up of very different values of the elements that go into them, and therefore a satisfactory presentation of a climate must include more than mere averages. It must take account, also, of

regular and irregular daily, monthly and annual changes, and of the *departures,* mean and extreme, from the average conditions which may occur at the same place in the course of time. Further, a determination of the frequency of occurrence and of the probability of occurrence of a given condition or of certain values of that condition is often of very great economic importance. Levees should be built to resist the *highest* floods; water-pipes should be buried deep enough to be safe from freezing in periods of *greatest* cold; buildings and bridges should be strong enough to withstand the *highest wind* velocities; gutters and sewers should be planned to take care of more than "average" downpours. Again, the frequency of occurrence of certain conditions, as, *e.g.*, of temperature changes of 25° or more, or of temperatures over 100°, or below, say, −40°, may be a very important item of information in certain climates. Similarly, especially for the farmer, the probability of occurrence of killing frost during a critical time in the growth of certain crops, or of rain during harvest time, is a significant part of practical climatic information. Or, to state it in very general terms, the more detailed is the available information about a climate, the greater is the value to man.

The first stage in climatological research is to bring together, correct, standardize and tabulate all the available meteorological observations. This requires patience, accuracy and enduring enthusiasm for a very fatiguing and monotonous task. "Pure" climatology concerns itself with the preparation of the numerical data. The second stage—and one that is naturally more interesting and more inspiring—concerns itself with the applications of these numerical results to the life and activities of man. That is the real aim and purpose of climatology—"pure" climatology is then superseded by "applied" climatology.

In order that I may indicate to you some of the innumerable ways in which our science is applied in the service of man, I have chosen a few examples, obvious, simple and doubtless to some extent already more or less familiar to you.

Let us take first a few cases from the border-zone between climatology and botany. After that we shall select other illustrations, from engineering, from insurance, from geology and from military science.

A map of the natural vegetation of the world is fully intelligible only when studied in connection with the distribution of rainfall and of temperature. There are, as is well known to all of you, three major zones or belts of natural vegetation: forests, grasslands and deserts. Each of these belts is broken up and modified, in a more or less irregular way, by the topography; the presence of mountains, plateaus, lakes and rivers, as well as by differences of soil and other controls, so that often the map of natural vegetation becomes a patch-work rather than a simple zonal sequence of forest, grassland and desert. Furthermore, man has himself very greatly changed natural conditions by cutting down forests, planting crops and irrigating deserts. In spite of all these modifications and changes, certain broad climatic controls remain and can easily be stated. Thus, palms, which may be taken in a general way as the typical trees of the tropics, are fairly closely limited in their natural extension into the higher latitudes of the temperate zones by a temperature of 68° F. for the average of the year. Indeed, so striking and so critical is this control that the line of 68° mean annual temperature has been generally accepted, certainly among climatologists, as the most logical boundary between the temperate and the tropical zones. Again, as we progress poleward from the temperate zones toward the Arctic or Ant-

arctic, it is found that the temperature of 50° F. for the warmest month of the year is a critical one. A line connecting all places that have this temperature runs around the world in a somewhat irregular course, bending poleward or equatorward according to the conditions of land and water and altitude, but in general marking fairly closely the polar limits of tree growth and of agriculture. For this reason climatologists have selected this isotherm of 50° for the warmest month as being the most logical boundary between temperate and polar zones.

The world's forests grow where the rainfall is fairly abundant and where the temperatures are not too low. Mean annual rainfalls ranging between 100 inches, or even more, and about 20 inches, are seen to occur where forests grow, the need of moisture being greater where the temperatures are higher and the evaporation is consequently increased. Grasslands are found with mean annual rainfalls of about twenty to fifteen inches, while semi-deserts or deserts are associated with rainfalls of ten inches or less a year. The foregoing are very broad generalizations. Forests are broken by grasslands; grasslands are interspersed with forests where the rainfall is more abundant and soil and other factors are favorable; plateaus and mountains in deserts, rising as islands of heavier rainfall, carry trees and become the sources of streams that flow down into the desert, providing water for local irrigation and for tree-growth—welcome oases for desert travelers. The life of primitive man is very largely controlled by the type of vegetation by which he finds himself surrounded. From it he secures much or all of his food; it provides him with raw materials; it largely determines his occupations; it supplies his clothing.

As my next illustration of an intimate and critical control of a specific climatic condition over man's use of the earth's surface, I have selected the mean annual rainfall line of twenty inches in our own country. I know of no more striking example anywhere in the world of the economic and historical importance of one specific climatic factor in the life of man.

The United States may conveniently be divided into two major divisions, separated by a transition zone lying in a general way along the 100th meridian. This meridian, running north and south, passes about centrally through North and South Dakota, Nebraska, Kansas and then continues southward across Oklahoma and Texas. The line marking an average annual rainfall of twenty inches roughly follows the 100th meridian. The eastern half of the country has sufficient rain in normal years, and produces crops cultivated by ordinary farming methods. To the west of the twenty-inch rainfall line there is a vast region where agriculture of the type characteristic of the rainier east is as a whole no longer found (except on the northern Pacific coast and in parts of California and of the northern Rocky Mountain district); where water, not land, is the measure of success. By climatic limitations, dry farming, grazing and irrigation are man's three methods of making use of the land—dry farming where the rain is most abundant; stock-raising where there is not enough moisture even for dry farming; irrigation over the limited areas where water is available. "Dead line" was the name given to this critical boundary in the early days. "East of it lies success," as the saying went, "west of it failure. Look out for the 'Dead line.'" Once the home of immense herds of bison which pastured on the natural grasses; then browsed over by millions of cattle; afterwards, in the days of the "boom" of the later eighties and even more recently, the scene of unhappy and

disastrous attempts to use them for large-scale agricultural operations of the eastern type, the natural limitations of the Great Plains have come to be fully recognized. They were never fitted to be a region of vast farms for raising crops by methods that take no account of the special climatic and soil limitations. They could not continue to support vast herds of cattle which exhausted the natural pasturage and perished in great numbers during dry seasons and in the severe winter cold and storms. They are available, here for dry farming; there for local irrigation from streams or wells, with small individual farms and cattle ranches; elsewhere, again, for grazing.

It gradually became clear that in many sections immense herds of cattle, roaming more or less at will and suffering heavy losses, were becoming less profitable than smaller herds, kept and bred under more careful supervision and provided with some forage in addition to that supplied only by the natural range. Local irrigation led to the development of small farms, with intensive cultivation of many general farm crops. The great cattle ranches of wealthy owners or of corporations have become less numerous, and the smaller holdings of individual farmers who combine stock-raising with the raising of varied crops and of feed for the cattle have increased. The whole history of this great region is one of an increasing adjustment on the part of man to his climatic environment and a recognition of the climatic handicaps.

I have referred to dry farming and to irrigation as characteristic and inevitable aspects of our dealing with much of that vast area west of what used to be called the "Dead line." Dry farming is farming without irrigation where the rainfall is too small for agriculture unless this rainfall is cared for and conserved in a special and peculiar way. The problem is essentially climatic. Dry farming is of such a comparatively recent date in this country that there are a good many questions regarding it which time alone can answer. One thing is certain. There is a pretty definite limit to the amount of land that can be irrigated. Water is not available for any more. As to the lowest mean annual rainfall limits for profitable dry farming in the western United States, I can not give an exact figure. Perhaps from ten to twelve inches would be a fair estimate, but there are exceptions to this rule. Where the mean annual rainfall is over fifteen inches, dry farming is generally practiced only where the distribution of the rainfall through the year is unfavorable or where evaporation is large. To quote a fair and conservative opinion of another, dry farming in many sections of the United States "has not been tried through a long enough period to make sure that it is more than a precarious occupation, sometimes profitable, occasionally disastrous; it is invited more by the low price of arid lands than by the certainty of crops; it can be best practiced by those who have enough hope or capital to survive one or two years of failure with two or three of success." "If you *can* irrigate, irrigate. Where you *can not* irrigate, practice dry farming," is good advice west of the "Dead line."

Irrigation is an expression of man's dissatisfaction with the amount or the distribution of rainfall. It is initially and fundamentally a climatic problem. Where irrigation is practiced, a wide range of crops can be raised, determined by local conditions of climate, soil, topography and demand. Irrigation means high price of land, relatively small holdings and a high degree of local cooperation. Being an expensive type of agriculture, it is to a large extent dependent upon economic controls.

Conditions in the west have gradually settled down to a reasonable adjustment on the part of man to the available water supply. It is now clearly recognized that the water available for irrigation is very limited, for it is obvious that all the water used in irrigation must have fallen somewhere as rain or snow, and precipitation over most of the far west is small at best. Most of the "Great American Desert," as it used to be called, must forever remain non-agricultural. But careful study of all possible sources of water supply will result in further extension of irrigation enterprises over limited districts that are today producing nothing but sage-brush and other natural types of arid-land vegetation. It has been estimated by competent authorities that if all available sources of water supply were fully utilized the potentially irrigable land in the west would amount to about double the present area of irrigated land. It is to be noted, however, that the cost of construction of irrigation works increases as less and less favorable projects are developed. The cost of land under the ditch and ready for farming may exceed the demand at the prices quoted.

To a superficial observer of our western "deserts" it seems as if irrigation must completely and successfully solve man's agricultural problems there. But here, as everywhere, the apparent solution of one problem gives rise to other new and unexpected problems. Nowhere is there a lack of struggle. When the ground-water level rises as the result of irrigation it causes a deposit of alkaline salts on the surface. Thus the irrigated desert has in places become an alkaline desert. The irrigation canals are bordered by weeds. From these, seeds drop into the water and are distributed over the fields and through the orchards, giving rise to another new problem. Thus the eternal struggle of man against nature goes on in varying phases.

Striking illustrations of practical studies of climatology in the service of man are found in the extension of the areas devoted to rubber and to cotton. Brazil for many years dominated the world's rubber markets. In the hot, damp Amazonian forests, *Hevea brasiliensis*, the Para rubber of commerce, found its natural home in a congenial tropical climate and in rich deep soil. From those vast forests, exploited by what in reality amounted to slave labor, came most of the rubber used in the United States and Europe. As far back as the later seventies, with a keen sense of commercial rivalry, England imported some seeds of the best Brazilian rubber trees to Kew Gardens, where they were carefully planted and developed. A study was then made of the climates of the British Far Eastern possessions, in order to find conditions of temperature, rainfall and soil most suitable to the establishment and extension of rubber plantations. Experimental plantings were undertaken. The intensive studies of the authorities of Kew Gardens—a beautiful example of an investigation in economic climatology—met with success. Brazilian rubber trees were introduced into Ceylon and the Malay Peninsula and Archipelago. "Tame" rubber gradually replaced the "wild" Brazilian rubber. Brazil lost her control of the world's rubber markets. The rubber plantations of the Far East, British and Dutch, now contribute nearly all of the rubber of commerce. It is not surprising that Great Britain developed the "Stevenson Plan," about which so much has been heard, to enforce the restriction of the rubber output in British possessions. This plan seems to have given rise to difficulties common in artificial attempts to regulate the laws of supply and demand, and the announcement of the abandonment of the scheme has not been a surprise. With the changing conditions in the Far East, the recent purchases of vast tracts favorable for

rubber cultivation in western equatorial Africa by the Firestone interests, and in Brazil by Mr. Henry Ford, it is clear that the rubber market is likely to undergo uncertainties and fluctuations in the near future. Further, several intensive climatic studies are being carried on in our own country with reference to the planting of selected varieties of trees or plants capable of supplying rubber, or at least substitutes for rubber, for use in certain branches of industry. In the Philippines, also, the development of rubber plantations is receiving increasing attention. There are doubtless considerable tracts in those islands suitable for rubber cultivation, provided labor and other difficulties can satisfactorily be overcome. It would seem, however, as a general proposition, that in the long run it will probably not be wise to undertake rubber production in the latitudes subject to typhoons, whose high winds are often very destructive to trees. I suggest, therefore, that the latitudes nearer the equator than about 10° N. are likely to be safer than higher latitudes within the so-called typhoon belt.

Another case of the application of climatological study to the extension of the area now occupied by an important commercial plant is that of cotton. Here again scientific and commercial sense have combined in an interesting way. The question for Europe has for years been: "How can we become independent of the United States in the matter of cotton, and also increase the area devoted to cotton-raising in order to supply the world's growing demand?" The American Civil War really started this movement, but the foundation of the British Cotton-Growing Association in 1902, and of similar organizations in France and in Germany, has opened a new chapter in this discussion. The British Cotton-Growing Association has been the motive power behind intensive studies of the possibilities of cotton-growing in countries under the British flag, and has carried through some excellent pioneer work in economic climatology, especially in Africa. Distinct success, or at any rate a fair degree of success, has been attained in parts of the Sudan, in western Africa, in Uganda and Nyasaland, in South Africa. The World War seriously interfered with these undertakings, and problems of labor, transportation and general financing have been serious handicaps to large developments. The British Cotton-Growing Association has also promoted cotton cultivation in India, and has increased the acreage in the West Indies. Other European countries have also taken part in this general movement.

South America offers a field for the extension of cotton-growing. From the necessarily very superficial study which I was able to make in certain parts of South America some years ago, I believe that the rather limited irrigated districts of Peru, now, and for many years back, devoted to cotton, can be considerably extended; and that Brazil, which had a distinct "boom" in cotton during our Civil War, can not only come back to its then acreage but even greatly increase it. The northern portion of the Brazilian plateau, south of the Amazon forests, seems to offer conditions of climate and soil which are favorable. There are no, or but very rare, frosts; no severe storms; abundant sunshine, and enough rainfall in normal years. Some years ago the Argentine Ministry of Agriculture had a study made of the northern Argentine provinces, and reported that most of the lowlands in that section of the country, and the valleys not above 1,000 meters in elevation, are suitable for cotton cultivation both as regards climate and soil. Probably, also, neighboring portions of Paraguay and the eastern Bolivian valleys may eventually prove suitable for cotton. But little of the Guianas is adapted for cotton-rais-

ing, and while the Valencia district of Venezuela produces a little cotton now, there seems little likelihood that there will be any great extension of the acreage devoted to cotton-planting in that country.

I would not be misunderstood in my prediction as to the future for cotton in South America. There are many very serious difficulties in the way of any rapid development of this undertaking, such as problems of an adequate labor supply, of transportation, of financial organization, and the like. Cotton-growing is very much more than a question of climate alone. There can not possibly be any rapid development, but it may not be too optimistic a view to expect in the future a considerable increase in cotton acreage in the districts I have mentioned. The day may not be so very far distant when South America may take a more important position in the world's cotton markets than it does to-day. Certain portions of Australia, also, where there is sufficient water, either supplied by the natural rainfall or obtained through irrigation, seem well suited to cotton-cultivation, which may in the future be considerably developed there.

Let us turn now to a wholly different aspect of the use of climatic data in the service of man. One of the most striking developments in the insurance business in the United States in the last few years is the very rapid increase in weather insurance of all kinds. We are all perfectly familiar with insurance against fire resulting from lightning, and perhaps also with that against damage by high winds. But less familiar, because less common, is insurance against damage by hail, by frost, by drought, by floods, by tornadoes. In Europe this whole business of insurance against weather risks is fully stabilized. It has for years been customary in England, for example, to take out insurance against loss of gate receipts on account of rain at cricket games and outdoor pageants. In this country this class of insurance is rapidly becoming popular. We insure motion picture companies against lack of snow if the picture is to be made as a snow scene; the proprietors of summer hotels and amusement resorts can insure against rainy week-ends; building contractors against loss of time resulting from unfavorable weather. A few years ago the Harvard Class Day Committee, for the first time, took out rain insurance for Class Day. Another very interesting recent development is insurance of eclipse expeditions against cloudiness during the eclipse. And so on.

It is clear that insurance is a necessary and legitimate business, that it should be conducted on such lines as to compensate the insured against loss in return for a reasonable premium, and should at the same time result in fair profits for the companies concerned. One of the difficulties in connection with some of the new forms of weather insurance is that the companies often have an insufficient knowledge of the climatological conditions and of the actual risks involved. Hence, premiums may be unreasonably high. The business is not yet stabilized. A good illustration of this situation, now rapidly being remedied, is the case of tornado insurance in the United States. Much tornado insurance used to be handled by farmers' mutual insurance companies, which distributed their risks without proper regard to the habits and characteristics of tornadoes. These violent whirling storms—the most intense atmospheric phenomena with which man has to contend—practically always travel in an easterly or northeasterly direction. Their path of destruction is very narrow—usually about a quarter of a mile wide. Now it is obvious that tornado risks should not be distributed in an easterly or northeast-

erly direction, for a tornado may wreck everything along that line. The risks should rather be distributed in a northwest-southeast direction. Then, if a tornado occurs, the damage done will be on a narrow path *across*, and not *along* the line of the insured buildings; a single company is extremely unlikely to suffer a very heavy loss, and the distribution of the risks is in accordance with the known facts of tornado occurrence.

In this whole matter climatology has much to offer in the service of man. What the insurance companies and those who insure need to know are the detailed facts concerning the distribution of the weather phenomena and the climatic conditions which are unfavorable. Thus, if we wish to insure gate receipts against loss because of a rainy day, we should know the probability of rain at the place and time in question. We should know at what hours the rain is most likely to come, and whether it will probably be heavy or light. Frost insurance, scientifically managed, requires information concerning the probable dates of first and last frost; the possible departures from those dates; the frequency of killing frost in the frost months, and so on. Tornado insurance should rest upon a full understanding of all that is now known concerning the distribution of tornadoes in place and in time, the location of the so-called "tornado belt," the districts either wholly free from those violent storms or only at very long intervals subject to them.

These few examples will indicate what is in my mind. Climatology is ready, and anxious, to put at the service of insurance companies all that is known concerning weather and climate. From climatic tables already available any one who is interested can inform himself as to the average conditions of rain, snow, frost, thunderstorms, tornadoes, gales, and so on, which may be expected in normal years. This information is in no sense a long-range weather forecast, as I have previously pointed out. But it does give a fair idea of the weather insurance risk under normal conditions, and is a sufficient basis for writing such insurance in a way that shall be fair both to insurer and insured.

Climatology, then, is ready to give all possible information and assistance to the insurance companies in this matter. On the other hand, also, weather insurance is stimulating climatological research. Thus, in the single item of the hourly distribution of rainfall alone, a bit of information of very great significance in rain insurance, the demand of the insurance companies for this information has resulted in the undertaking of numerous studies of this particular aspect of rain and snowfall. Our general climatological knowledge has already been distinctly improved and made more complete by this new development of weather insurance. And this mutual cooperation is but beginning. I look forward to a distinct advance along these lines, for the common advantage of the science of climatology on the one hand and of the business of insurance against weather risks on the other.

So many engineering problems concern outdoor construction and operation that weather and climate are necessarily critical factors. Buildings must be constructed to withstand the maximum wind pressure that can ever occur. Bridges across rivers must be firmly anchored on piers that can not be carried away during the greatest floods. If built across what are usually dry canyons in the mountains of arid regions, it must be remembered that sudden "cloud-bursts" are characteristic of such localities, bringing downpours which may fill these narrow valleys to a depth of many feet of water in a very short space of time. In railroad construction through mountains

where heavy snowfalls and avalanches are known to occur, special provision has to be made on this account. The famous "Forty Miles of Snowsheds" on the Southern Pacific Railroad where it crosses the Sierra Nevada Mountains between Sacramento and Reno are a striking illustration of the way in which railroad engineers have to meet climatic handicaps. These sheds must be able to support the maximum weight of snow that may fall upon them. Further, the danger from fire is so great that watchmen have to be kept constantly on guard, especially in the dry season of summer, and trains equipped for fire-fighting are in readiness for immediate use. All this adds greatly to the operating expense of a railroad. On one of our eastern railroads, a few winters ago, snow removal after one heavy snowstorm cost $25,000 for each inch of snow that fell. This sum included the actual work of snow removal, and also the extra motive power, the cost of demurrage on freight cars and other similar expenses.

Before undertaking any irrigation enterprises, as in our own arid or semiarid west, it is essential to have a very accurate knowledge of the amount of the available water supply. To secure this information, rain-gauges must be installed on the watersheds, and, as in many parts of the west, surveys must be made of the amount and character of the snowfall, whose melting supplies most of the water used during the spring and summer months. It is sheer folly to spend money in constructing dams and reservoirs if the available water supply is to prove inadequate, or if the amount of water is ever to be so great that dams will burst under the pressure. For most of the important snowfields in our western mountains there is already available sufficient information on this point to serve our present needs, but as the demand for more irrigation becomes increasingly insistent in the years to come further data must be secured. The heavy snows of the Sierra Nevada Mountains in California have well been called "the life-blood of the state," and those who have visited California have enjoyed what the melting Sierra snows provide.

No modern city water supply is planned without a very thorough study, extending over many years, of the rainfall over the area where the reservoirs are located, and no one watches more carefully the amount of precipitation from day to day, and from storm to storm, than he who has charge of a great city's water-works.

A very recent illustration of the importance of a thorough study of local weather and climate is seen in the preliminary stages of the establishment of air-ports. After the World War the story leaked out that during the war an army air-port was established, necessarily very hastily, somewhere in the British Isles. No adequate preliminary study of local weather was made; thousands of pounds were spent in the preparation and equipment of the airport; but the location proved wholly unsuited to its intended use because of the erratic and dangerous character of the winds. This matter is now managed very differently. I happened to be in San Francisco last June, and while there I made inquiries concerning the new municipal air-port. The city for a year employed two expert meteorologists, loaned by the Government Weather Bureau, who made a very thorough survey of the atmospheric conditions in the locality where it had been planned to establish the air-port. This survey included the upper-air conditions, as determined by means of free balloons, as well as the surface conditions. The work has been completed, and the report has been written. Thus, in connection with the rapid development of flying in all its aspects, climatology is already

making important contributions, and will increasingly prove its helpfulness in making aviation safer.

An architect came to me a few years ago and asked me to tell him exactly what he should plan for in building roofs so that they would support the greatest weight of snow that might ever rest upon them. The question was a reasonable one, but the answer was not quite so easy to give in the precise figures that were desired. Our ordinary numerical data on snowfall include the mean annual and mean monthly depth of snow, the number of inches on the ground at the middle and end of each month, and so on. But they do not give the maximum depth on the ground at *any one time* during the period of observation. Even if they did, as the weight of snow depends on its density, and the density is not tabulated, the exact weight, as a water-equivalent, is unknown. A fair approximation may, however, be reached in this matter by taking the greatest depth of snow on the ground at the middle or end of any month noted during the period of observation, assuming that that snow was at its greatest possible density and then calculating its weight per square foot. Nevertheless this is not altogether a satisfactory method, and engineers and architects would be benefited if our snowfall records were more complete. I believe that many city building ordinances regarding the weight which a flat and a sloping roof must be able to support might well be revised.

The student of geology and of physiography finds himself at every turn confronted with climatic problems, and can make little progress unless he is familiar with the larger characteristics of climates and with the controls of those climates. If he investigates that most interesting chapter of our earth's history which has to do with the climates of the geological past, he can not evolve any sound hypotheses to account for glacial epochs and interglacial epochs without understanding how our present climates are produced. A climatologist who attempts to read the vast literature dealing with fossil climates—paleo-climatology this branch of our science has come to be named—will inevitably be struck by the fact that many fantastic explanations of past climates would never have been attempted had their authors been familiar with the principles of climatology. Extraordinarily difficult and complex these problems of paleo-climatology surely are. We are still very far from any satisfactory solution of them. Climatologists, as well as geologists, are baffled to-day as they were fifty years ago. But we are all the time making progress, and while the goal is still far distant, we look forward to its being reached. As climatologists we may as well frankly confess that we have no satisfactory explanation to offer of the very puzzling facts which geology has beyond question established in regard to the ice ages and interglacial periods.

The weathering of rocks is immediately controlled, to a large extent, by climatic conditions. In high latitudes, where the ground is snow-covered for part or all of the winter, chemical decomposition must largely cease. Here the actions of frost and of ice—mechanical rather than chemical processes—are highly important agents in promoting rock disintegration. On the other hand, in the rainy portions of the tropics, where, near sea-level, frost and snow and ice are unknown, chemical decomposition, resulting from frequent and heavy warm rains, becomes of paramount importance. Deep decomposition of the rocks is inevitable, and tropical soils therefore have certain typical and well-known characteristics. In deserts, especially deserts at considerable elevation above sea-level, the rocks are

subjected to excessive heating by day and cooling at night. The resulting expansion and contraction crack the rock surfaces; they split, and thus even in excessively arid regions rock disintegration goes on. Blowing sand wears down these rocks and rock fragments, and gradually, as they become smaller and smaller, they themselves become a part of the sands which surround them. Any one who has had the wonderful experience of spending the night under the stars in a high desert among boulders or cliffs has heard the sharp reports like pistol shots which accompany this process of rock disintegration.

To my thinking, the most logical classification of rivers from the point of view of their human relations is one that is based upon climate, and yet, so far as I know, no such classification is in use. There are rivers with a uniform water supply throughout the year, fed by well-distributed rainfall or by rainfall at one season and melting snows at the other. Most rivers have periods of high water and of low water, depending on the seasonal supply. In low-water times they may completely dry up, as is the case, for example, with many of the rivers in California in summer, while during the rainy season or the season of melting snows, deep water or floods will be the rule. Thus many rivers are navigable during part of the year only, and commerce is interrupted during the remaining months. Many rivers flowing into latitudes of severe winters are completely frozen for months each year. Transportation by water then ceases, and travel is often best accomplished by using the frozen surface as a highway. From the mountains surrounding deserts streams flow down onto the arid lower lands and wither away there, in sinks or playas or salt lakes. It is only when the water supply is very abundant, as in the case of the Nile, for example, or of the Tigris and Euphrates, that a river can flow for a long way through an arid region and persist until it reaches the sea. To what extent man can make use of rivers for purposes of travel and transportation, and how far floods may lay waste his cultivated fields or carry away his houses and his bridges, depends, after all, upon the amount of water in the channels.

Erosion by running water is suspended wherever temperatures below freezing last sufficiently long to turn streams into ice.

If the rivers on the windward side of a mountain range are well supplied with water while those on the opposite side are in what is known as the "rain shadow," and are shallow and feeble, the former, other things being equal, will have the best opportunity for work, and will extend their headwaters back so that the water-parting is no longer on the crest of the mountain range but may even be pushed out onto the lowlands on the lee side. Thus, rainfall which originally found its way to the sea on the lee side may eventually be taken as it were across the range to the windward side. This process inevitably shifts the divide in places from the crests of the mountains onto the leeward lowlands. Such a situation has arisen along the southern boundary between Chile and Argentina. Chilean rivers have actually robbed Patagonian rivers of their headwaters, and have in certain instances shifted the water-parting onto the Patagonian plains. In other words, some Chilean rivers start in Patagonia, and what were formerly Patagonian lakes along the eastern base of the Cordillera now drain into the Pacific Ocean. The fact that Argentina rather naturally regarded the crests of the Cordillera as the boundary, while Chile equally naturally considered the water-partings, even when on the Patagonian side, the boundary, really had much to do with the famous boundary dispute between

Chile and Argentina a number of years ago. The difficulty was fortunately adjusted by arbitration. The famous statue, the Christ of the Andes, was erected to commemorate the peaceful ending of what threatened to be a disagreement settled by war. This is a striking illustration of the part played by rainfall, acting through normal physiographic processes, in connection with an international boundary.

There are many other illustrations of geological processes in which climate is concerned. The nature and colors of soils are largely climatically controlled. The action of waves along shore in eroding cliffs, building sand-bars and beaches, and the like, varies with the height and the strength of the waves, and is therefore to a considerable extent dependent on the presence or absence of storms, either near by or at a distance. Storm waves are propagated to great distances from the locality in which the storm is active. Waves run so far ahead of the whirling hurricane winds that produce them that we may often see great rollers coming in on our beaches when the center of the disturbance is far away to the south or southeast. Physiographic forms in large measure correspond to the climate of the region in which they are found, and a skilled physiographer may interpret the climate from the form or, knowing the form, can describe the climate. There are arid-land forms of talus slopes and alluvial fans and of mountains partly buried in their own waste. There are wet-climate deltas and terraces and valley forms. There are the moraines and eskers and other special features of regions once glaciated. A physiographer needs to know his climates if he would fully understand the features of the earth's surface which it is his business to explain. Many valuable deposits of immense economic importance to man owe their preservation to existing climatic conditions. Thus, the famous nitrate beds of northern Chile would dissolve and disappear were that region to become rainy. It is now one of the driest deserts in the world. From it has come vast wealth. The last thing in the world that the people who live in that desolate nitrate desert desire is rainfall. Similarly, the great guano deposits on the Peruvian islands are preserved, with all their valuable chemical properties for soil enrichment, because of the lack of rainfall. Should the great Humboldt Current off the west coast of South America slacken or change its course, should the southerly winds along the Chilean and Peruvian coasts change their direction, the nitrate and guano would cease to exist. A very special and peculiar combination of climatic controls has preserved these two deposits which have been of such immense economic significance to Chile and Peru.

My final illustrations of the part played by climatology in human affairs I shall take from military science. As far back as we have any record of military campaigns and of battles, there is mention of the part played by weather and climate in warfare. Famous cases of this kind were the destruction of the Spanish Armada by a severe storm and the winter retreat of Napoleon's army from Moscow. The evacuation of Boston by the British was hastened by a violent storm which drove some of the British vessels ashore and prevented the debarkation of the soldiers in order to drive away the Revolutionary army from the fortification of Dorchester Heights. Our own Civil War furnished innumerable instances of weather controls over the movements of troops and guns.

It remained for the World War, however, to bring into startling prominence the factor of weather in warfare. There are two aspects of this subject. Military commanders must have knowledge of coming weather as many hours in ad-

vance as possible in order that they may know what conditions to expect in the immediate future. This information is necessary in planning movements of troops, in organizing bombing expeditions, in regulating artillery firing. The World War was the first in which regular weather forecasters were attached to the headquarters staff, and in which scientific weather forecasts were made with the help of an organized body of meteorological observers. Weather forecasting is, however, only one side of the picture, and it is not the one with which we are here directly concerned. The other side concerns a thorough knowledge of the general climatic conditions of the area where the fighting is to be done.

Military commanders should know beforehand whether they will have to deal with heavy snows, with frequent heavy rains, with severe cold, with much low-lying cloud, with fog, with high winds, with dry spells, with dust, with mud, and so on. All this information is readily obtainable in the regular official climatological summaries and in the discussions that usually accompany these tabulated data. It is worse than folly for a military expedition to be taken into a dry region, for example, without making proper provision for a water supply, or into a country of severe winter cold without adequate warm clothing, or into an area of heavy snows without preparation for transport under such conditions. In other words, the high military command should have all possible advance information concerning conditions of temperature, rain or snowfall, winds, clouds, and the like.

The great war furnished many examples of a very complete ignorance on the part of those who should have known about these matters. Each war zone had its own special problems. In the western war zone—the only one in which our own troops were engaged—the outstanding climatic characteristics are the frequent rains at all seasons of the year, the abundance of cloud, the low-lying night fogs, the absence of any extreme cold, the occasional short spells of heat in summer, the irregular varying winds. The climate in that area is a modified continental climate, less severe than that in New England, more like that of the north Pacific coast. Farther east, in Poland and in eastern Prussia, the winters are more severe; there is more snowfall; the cold lasts longer. In fact, Warsaw and Boston have a good deal in common climatically. Much of the fighting in the Italian war zone was carried on under conditions of extraordinary difficulty among the deep snows of the mountains, where avalanches and great cold and almost impossible conditions of transport obtained. The men marched on skis or snowshoes, and used white sheets to make themselves less visible on the snow.

In Mesopotamia the terrific heat and the lack of water caused indescribable suffering among the British troops. Temperatures in the hospital tents were reported as over 130°. Cases of sunstroke and heat prostration were common. The men were so thirsty that, in spite of all orders to the contrary, they drank the polluted water of the Tigris.

But one of the very worst examples of lack of preparedness against climatic handicaps came in the Gallipoli campaign. The Gallipoli Peninsula is in that portion of the Mediterranean climatic zone where dry summers are typical and inevitable. The British troops were landed, and ordered to fight, with an absolutely inadequate supply of water. No proper provision had been made to meet a condition as certain to be found there as night is certain to follow day. After long delays, water was brought from the ships and supplied to the troops, but so inadequate was that supply that the men cut holes through

the hose which carried the water in order to relieve their unendurable thirst, and for a part of the time the daily ration was half a pint of water per man. No wonder that the general commanding the British forces, in his official report, said that much of the lack of success of his campaign resulted from an insufficient water supply. Towards the autumn, when the winter cold set in and snow fell, the suffering among the Anzac troops was again tragic and heartbreaking. Failure to anticipate all these conditions was, perhaps, excusable because of the need of haste in carrying through the Gallipoli campaign, but nevertheless the climatologist sees in this disastrous and unsuccessful undertaking a very sad and a very striking illustration of the need of preparedness on the climatological side in the conduct of a military campaign.

X-RAY APPLICATIONS IN EVERY-DAY LIFE

By Professor GEORGE L. CLARK

UNIVERSITY OF ILLINOIS

I

THE applications of X-rays are becoming so numerous and important in the daily life of every man that it seems of interest to take brief account of some of the achievements and possibilities of this great research agent. To most folks X-rays are a mysterious invisible instrument with which the physician is enabled to see, on a photographic plate or a glowing screen, broken bones or an imbedded bullet or a pin caught in a child's throat, or with which the dentist may examine the roots of an ailing tooth. Some of us may have had our last pair of shoes scientifically fitted by seeing for ourselves the actual positions of the bones of the feet. The pioneer application of X-rays in medical diagnosis is still one of the greatest, but there are many new and equally interesting fields of usefulness. The roentgenologist, after locating an internal tumor or cancer with X-rays, treats it with these rays as a therapeutic agent; the biologist and botanist face the great processes of natural evolution fearlessly and produce by direct irradiation of fruit-flies or tobacco plants an astonishing acceleration of a thousand per cent. in the mutation of species and thus profoundly affect the characteristics of future generations; the physicist has been using X-rays as magic eyes with which to explore the interior architecture of atoms, and finds there marvelous infinitesimal planetary systems ordered by the laws of a rational universe from the simplest hydrogen atom to the most complex uranium atom; the chemist is discovering new chemical elements by measuring the X-rays characteristically emitted by materials when bombarded by electrons; to the chemist also is being revealed the fine structure of the unit building blocks of all matter; and now industry is finding X-rays of immeasurable assistance in the solution of some of the most difficult problems of producing commodities of certain and satisfactory quality. For X-rays yield the knowledge of the ultimate construction of matter which determines even the most practical and useful properties.

We may now ask, what are these remarkably versatile X-rays? In every respect are they identical with ordinary light except that the wave-lengths are only 1/10,000 as great, on the average, as visible light. They are electromagnetic vibrations propagated as waves or as tiny bundles of radiant energy through space without transference of matter. X-rays, the cosmic rays which come from the far reaches of the universe and are able to penetrate eighteen feet of lead, the gamma rays from radium, the ultra-violet, infra-red, and radio waves are all like light except in wave-length.

In all this great range of rays, from those only 1/100,000,000 cm long to those hundreds of meters long used in radio broadcasting, the human eye is sensitive only to that extremely narrow band we call light. Because X-rays are shorter than light it follows that they are more penetrating, that they should pass through materials opaque to light, and that they should be associated with a finer subdivision of matter than is apparent by examination in visible radiation. As a matter of fact, we find that X-ray wave-lengths are of the same

order of magnitude as the sizes of the ultimate atoms of all material things. By means of X-rays as the messenger, therefore, the knowledge of the true unit building blocks of matter and their interrelationships is gained.

While X-rays penetrate matter opaque to light, they are absorbed differentially because any inhomogeneity or defect in an object has a different density and absorbing power than the main body of the material. Hence X-rays which pass through such an object will have varying intensity, and when they strike a photographic plate a shadowgraph of the specimen is registered which may also be visually observed on a fluorescent screen. Observation of bones through the less dense tissues is of course the most familiar example of this science of radiography. Think what medical and surgical diagnosis would be to-day without X-rays, not only for absolute information on bone fractures and diseases but also for tuberculosis, tumors, gallstones, blocking in the spinal column and almost all the long list of pathological conditions of the body!

A great experience is accumulating to prove that even malignant internal cancers, too often unsuspected until far advanced, may be successfully cured or at least greatly alleviated by X-ray and radium treatments if diagnosed in the early stages. Radiographs of the skull are so individualistic that they will soon supplement finger prints as a method of identification of persons. In the University of Illinois recently a curious and obscure disease of carp in the Illinois River which curtails normal growth has been diagnosed as a type of rickets from X-ray photographs where dissection methods largely failed. In a great exhibit of medical X-ray photographs such as that at the recent meeting of the Radiological Society, one is deeply moved by the enormous number of ills to which these bodies of ours are subject, and consequently by the advisability of regular X-ray examinations even in good health.

There are also many inanimate things whose ills may be diagnosed just as successfully. One of the most important is the examination of metal castings for presence of internal gas cavities, sand and slag inclusions, pipe cavities, porosity, cracks and metal segregation. The result is perfectly sound castings where the safety of human life is demanded, as in high-pressure power plants, oil stills and aircraft motors. The greatest X-ray laboratory devoted to this subject is located at the Watertown Arsenal in Massachusetts. Some of the other radiographic applications in this country are: the examination of welds for soundness; of coal for slate and ash; of minerals for classification; of golf-balls for symmetry of the center; of cord tires for adhesion of rubber; of reclaimed rubber for nails and foreign matter; of shells and grenades for proper filling of explosive; of wood, particularly when used in airplanes, for wormholes, cracks and knots; of trees and telephone poles for interior soundness; of logs in veneer manufacturing plants for imbedded nails liable to ruin cutting blades; of walls for hidden pipes and wires; of mystery packages, some of which may be sent as undesirable gifts by anarchists; of false-bottom baggage evading customs officials; of metal pipes and capillaries for measurement of internal diameters; of clogged gasoline lines; of radio tubes for proper position of electrodes; of glass and pigments, and of Swiss cheese for the location and size of the highly prized holes. The Fogg Art Museum at Harvard University and the Metropolitan Museum in New York are X-raying old pictures and discovering retouching and sometimes infinitely more valuable masterpieces entirely painted over. And so, many other interesting shadowgraph applications might be enumerated.

Whenever there is a need to examine the interior of any object, X-rays provide in a sense a powerful extension to the limits of our vision. Now even the science of Egyptology lays a claim to this tool, for most of our knowledge of ancient anatomy is derived from radiographs of mummies!

II

In beginning our survey of the applications of X-rays in every-day life, we found that these rays are like ordinary light in every respect except that the wave-lengths are much shorter. On this account, X-rays will penetrate matter which is opaque to visible light and register shadowgraphs of bones, teeth, defective steel castings, welds, golf-balls and many other objects, the denser portions of the interior standing out in relief against the portions which do not absorb X-rays so readily. This constitutes the great X-ray science of diagnosis, whether it be medical or the examination of a vast number of inanimate objects for internal gross structure or defects. But in disclosure of gross structure X-rays have far from exhausted their possibilities. If we but use them properly, they will lead directly to a knowledge of the *ultimate* structure of matter, clear down to the atoms and molecules which constitute the very minute unit building blocks of the material universe. Practically every property, useful and otherwise, of the things we know and use every day, depends fundamentally upon the size and shape and number and arrangement in space of these unit building blocks, which are far too small to be seen by a microscope. If these are known from our X-ray examination of materials, then it follows that we shall discover with absolute finality the primitive cause of a satisfactory or unsatisfactory behavior of an object which we can see and use. Suppose we take a strip of iron and slightly etch it with acid. The crystal grains are now easily seen with the eye, each appearing perfectly homogeneous. Under the microscope, however, a homogeneous grain may show a heterogeneous fine structure. One of these microscopic units with X-rays indicates that it in turn is built up of ultimate crystal units. What is this unbelievably small unit crystal of iron—this block which is combined with an enormous number of others just like it to give the crystal grain which the human eye may see? We know it to be a tiny cube with an atom of iron at each corner and one in the center; the cube measures less than 3/100,000,000 cm on a side; it is the last thing that is still solid crystalline iron—its properties are those of the visible crystal grain of iron—it is the ultimate iron. Other metals, such as tungsten and chromium, have the same type of ultimate cubic architecture, but these units have different sizes than that which characterizes iron. Still other metals, such as the ductile aluminum, silver and gold, have a different type of crystal unit. The fact that this unit crystal is built in so orderly and perfect a fashion explains why X-rays yield such remarkably fundamental information. Most of us are acquainted with the fact that if we rule parallel lines very close together on glass or metal, we have a grating which will diffract ordinary white light and like a prism spread the beam out into a rainbow or spectrum. Now if X-rays are like light they should be similarly diffracted by a grating, but it has never been possible to rule these lines sufficiently close so that the X-rays with their far shorter wave-lengths are affected except under very special conditions. Thus, from the date of discovery of X-rays by Röntgen in 1895, till 1913, there were no gratings known for the analysis and measurement of beams of X-rays, although it was recognized that an average wave-length of X-rays was

1/100,000,000 cm, and that a grating must have parallel spacings of the same order of magnitude—that is, about the size calculated for the ultimate atoms themselves. It was von Laue, a German, who finally reasoned that nature has literally deluged us with perfect X-ray gratings—namely, crystals of every conceivable kind. For in a crystal the atoms or molecules are marshaled perfectly row on row like West Point cadets except that the crystal is three-dimensional and has equidistant planes of atoms, spaced a few hundred millionths of a centimeter apart, which diffract X-rays. Von Laue ordered the experiment performed of passing a beam of X-rays through pinholes in lead blocks, and then through a crystal of zinc sulfide with a photographic plate behind the crystal to register the result. The plate showed an array of sharp spots forming a figure of perfect symmetry—an eloquent verification of the prediction that crystals are built up from their very beginnings in perfect order not only for those specimens with beautiful faces like a diamond, but also for materials which outwardly seem to manifest no such regularity. And now even liquids, which we have always classed as distinctly amorphous because molecules are free to move about, manifest remarkable attempts at organized structure, for they produce definite though simple X-ray diffraction patterns. Thus do we arrive at a great branch of X-ray science whose achievements have already formed one of the most brilliant pages in science, and yet whose possibilities are well-nigh limitless. For with some known crystal as a grating we can measure the whole unknown range of X-ray wave-lengths or, *vice versa,* with X-rays of known wavelength we can analyze the unknown ultimate structure and unit dimensions of new crystals, and now even of powders, jellies and liquids.

Before proceeding to the practical application of this fundamental method of research to the problems of structure, properties, manufacture and use of chemicals, metals, alloys, textiles including rayon and silk, rubber, ceramics, paints, lubricants, waxes, cement and numerous other materials, a brief description will be given of the new X-ray laboratory in the chemistry department of the University of Illinois which is primarily devoted to these fine structure studies. The essential parts of an X-ray apparatus are the X-ray tube, a source of high potential, methods of defining the X-ray beams through small pinholes and slits, water-cooling systems for keeping the tubes cool during continuous operation, various protective devices for the experimenter against X-rays and high voltages, and photographic equipment. An X-ray tube of the Coolidge type is an evacuated bulb in which there are two electrodes, a tiny spiral of tungsten wire which is heated to incandescence by an electric current, and a smooth-faced metal target opposite. The hot wire emits electrons as discovered by Edison. When a voltage of 30,000 to 80,000 volts is applied, these electrons are driven like miniature cannon balls across the gap and bombard the target. They are stopped and their energy converted to X-radiation which passes out through the tube walls. The laboratory has three complete apparatus units with which it is possible to obtain X-ray photographs of twenty or more specimens simultaneously. The exposures range from a few minutes to as many as one hundred hours, depending upon the material. Another tube which depends upon residual gas instead of a filament for operation produces so powerful a beam of X-rays that results are obtained in only about one tenth the time usually required. An ingenious spectrograph makes it possible to use several diffraction methods, depending

upon the material and the type of information desired.[1] Still another X-ray unit in the chemistry department is being devoted solely to further study of the new element illinium, discovered by Professor B. S. Hopkins and associates. Some of the interesting problems under investigation on the structure and properties of materials will be considered in the next section.

III

We have now found that X-rays lead us from information concerning the interior gross structures of material to knowledge of ultimate fine structures far beyond the power of any microscope. Nature has built all solid crystalline matter according to so orderly a plan that all the atoms and molecules lie on parallel planes which are spaced at distances which compare with the short wave-lengths of X-rays. Thus crystals, each one in its own definite characteristic fashion, diffract X-rays just as finely ruled lines on glass diffract ordinary light. We are able to deduce the structure and size of the unit crystal cell serving as the architectural pattern which upon multiplication in all directions builds up the visible crystals. We determine the size, shape and constitution of the single brick in an apparently homogeneous structure hundreds of millions of times larger. If this brick is slightly deformed by stress the X-ray patterns indicate it. If the material is a single crystal grain with all the tiny ultimate units perfectly aligned, or if it is a powder or aggregate of small grains chaotically heaped together, or if it is an aggregate with the grains oriented in a common direction as in asbestos or cotton fibers, or metal wires or rolled sheet, the X-ray patterns are perfectly characteristic. There are some twenty different types of fundamental information which may be ascertained from diffraction data, and these account in the realest sense for the actual behavior of materials.

So rapid has been the growth of this chemical science of X-rays that more than 500 kinds of crystals have been singularly analyzed, ranging in complexity from common salt or aluminum to very complex silicate minerals[2] and organic compounds. Prior to X-ray analysis the chemist's knowledge of the solid state was decidedly limited and he strove to avoid this by melting or dissolving the substance before he attempted to do anything. Now he is trying to crystallize everything and determine the structure as our knowledge advances of the amazingly orderly forces which hold atoms and molecules in marshaled array in space. We are now thoroughly familiar with the crystalline architecture of almost all the useful metals and alloys. We understand that the ductility and malleability of aluminum, copper, gold, silver, and the brittleness and hardness of chromium, tungsten or molybdenum are properties directly related to the plan of building in the unit crystal. We can picture exactly from the X-ray data how zinc atoms elbow their way into the little unit cubes of copper and literally push the sides of the tiny structure apart to form brass. We now recognize four kinds of solid iron: α, β, γ, δ, depending upon the temperature and differing in magnetic properties, but X-rays tell us that α, β and δ iron have exactly the same crystalline structure, and that magnetism is therefore not a property residing in crystalline structure. So, the whole problem of the constitutions and range of stability of metals and alloys is coming to be known and properties definitely predicted. And now, in addition,

[1] A complete description of the laboratory illustrated with photographs of apparatus and typical diffraction patterns is presented in a paper in *Industrial and Engineering Chemistry*, 20, December, 1928.

[2] The compound $H_4[SiO_4W_{12}O_{18}(OH)_{36}]$ has been analyzed recently in the writer's laboratory.

the processes and results of fabrication and heat treatment lead us to a new industrial science. When a metal is drawn into a wire or rolled into a sheet remarkable changes occur in X-ray patterns. The mechanism of working may be quantitatively deduced—for example, that in an aluminum wire every tiny ultimate cube is turned so that the cube diagonals are all parallel to the wire axis, or that in a copper sheet all the little cubes with one atom of copper at each corner and one in the center of each face lie with a cube face in the plane of rolling. All such worked metals are obviously characterized by strongly directional properties, and it is the task of heat treatment to remove this condition, particularly if the metal is to be formed into useful articles. There is no more remarkable achievement of X-rays than the commercial control of annealing which will assure a uniform product of highest quality upon the basis of absolute knowledge of recrystallization processes. With such a control a technique of manufacture inevitably results which involves no greater expense or difficulty.

Again and again X-ray researches have this background of higher standards, better quality, knowledge of the ultimate and the diagnosis and alleviation of ills of every kind. It is little wonder, then, that there is kindled in the worker a burning enthusiasm which drives him on to explore new fields of application for this great science.

It is a common belief that heat-treating metals for a long time at low temperatures in order to remove strains and directional properties achieves the same results as annealing for a short time at high temperatures. New X-ray studies show that this precept is far from true, particularly for silver and copper. In the presence of five hundredths of one per cent. of iron the recrystallization temperature of silver is brought down to room temperatures, and all silverware under these circumstances would soon be ruined. As a matter of fact this amount of iron *is always present* except in very specially refined silver, but its deleterious effects are always offset by the presence of the same slight amount of copper. This curious metallurgical fact as ancient as silver itself has come to light after hundreds of years through the agency of X-ray analysis.

Cast steel is characterized by an X-ray pattern which clearly shows a condition of great internal strain, even though it may be free of gross imperfections. The purpose of heat treatment is to relieve this condition, but until now there has been no control method sensitive enough to discover the *best* annealing technique so that the ideal structure may be obtained. From X-ray data alone it was possible in this laboratory recently to plot regions of equal strain in a large casting, and thus to predict where it would fail or how it should be annealed properly. As a result several large manufacturing plants have based their annealing methods on this scientific research basis instead of empiricism. Similarly, we might describe X-ray studies of the cause and prevention of transverse fissures in steel rails, which have caused so many wrecks, the proper manufacture of electric steel with lowest magnetic loss, the proof of the great superiority in terms of ultimate structure of welds made in a hydrogen atmosphere as compared with the ordinary arc method, the desired structure for aluminum alloys, the changes during metal fatigue, and many other problems. Every metal product which finds usefulness in our daily life is a potential subject for X-ray fine structure research—and then only a single possible field has been touched.

Space permits only a brief enumeration of a few representative X-ray studies on non-metallic materials now

being made in the laboratory at the University of Illinois and elsewhere.

Asbestos: A clear differentiation between numerous varieties appearing outwardly the same but differing widely in practical behavior, and a method of identifying the mines from which various specimens of the same type come;

Lime: Discovery of the cause of plasticity and methods to render non-plastic lime useful;

Enamels and pigments: Composition, particle size and crystallization as functions of covering power, tint, wear, etc.;

Lubrication: A definite knowledge of mechanism in the lining-up of long grease molecules in successive layers like a stack of carpets with the pile of each carpet representing the molecules which slide over each other instead of one metal surface on another;

Waxes, soaps, alcohols and other organic compounds: The analysis of crystalline structure, actual measurement of the sizes of molecules, the testing and verification of the structural theories of organic chemistry (as for example, absolutely definite proof of the benzene ring);

Ceramic materials: Construction, transformations and internal strains, as in spark plugs;

Rubber: The discovery that this remarkable substance develops a crystal-like fiber pattern upon stretching (as does also a muscle fiber), analysis of which removes much of the conjecture from our scanty knowledge; the development of a method of stretching rubber 10,000 per cent. to threads insoluble in the solvents which usually dissolve rubber easily; and the establishment of these unique criteria never yet found in artificial or synthetic rubber;

Textiles: The behavior and constitution of the crystalline threads of cellulose and silk, and the deduction of a vastly improved type of rayon;

Catalysts: The deduction of optimum constitution and particle size for high pressure synthesis of methanol and other products.

Gelatine, biological structures, road materials, paints, nitrocellulose explosives, lacquers and transparent wrappers, paraffin, the cause and prevention of cracking of patent leather, liquids of all kinds, carbon, cement, adhesives, paper, the tiny objectionable stones in pears, electroplating, food products—all of these and many more materials are yielding their secrets of constitution and of their good or bad practical behaviors in everyday use to the searchings of X-rays. Though these rays move in mysterious ways their wonders to perform, they are serving mankind every day in the cause of better materials, better health, better knowledge of the universe ordered by a supreme intelligence.

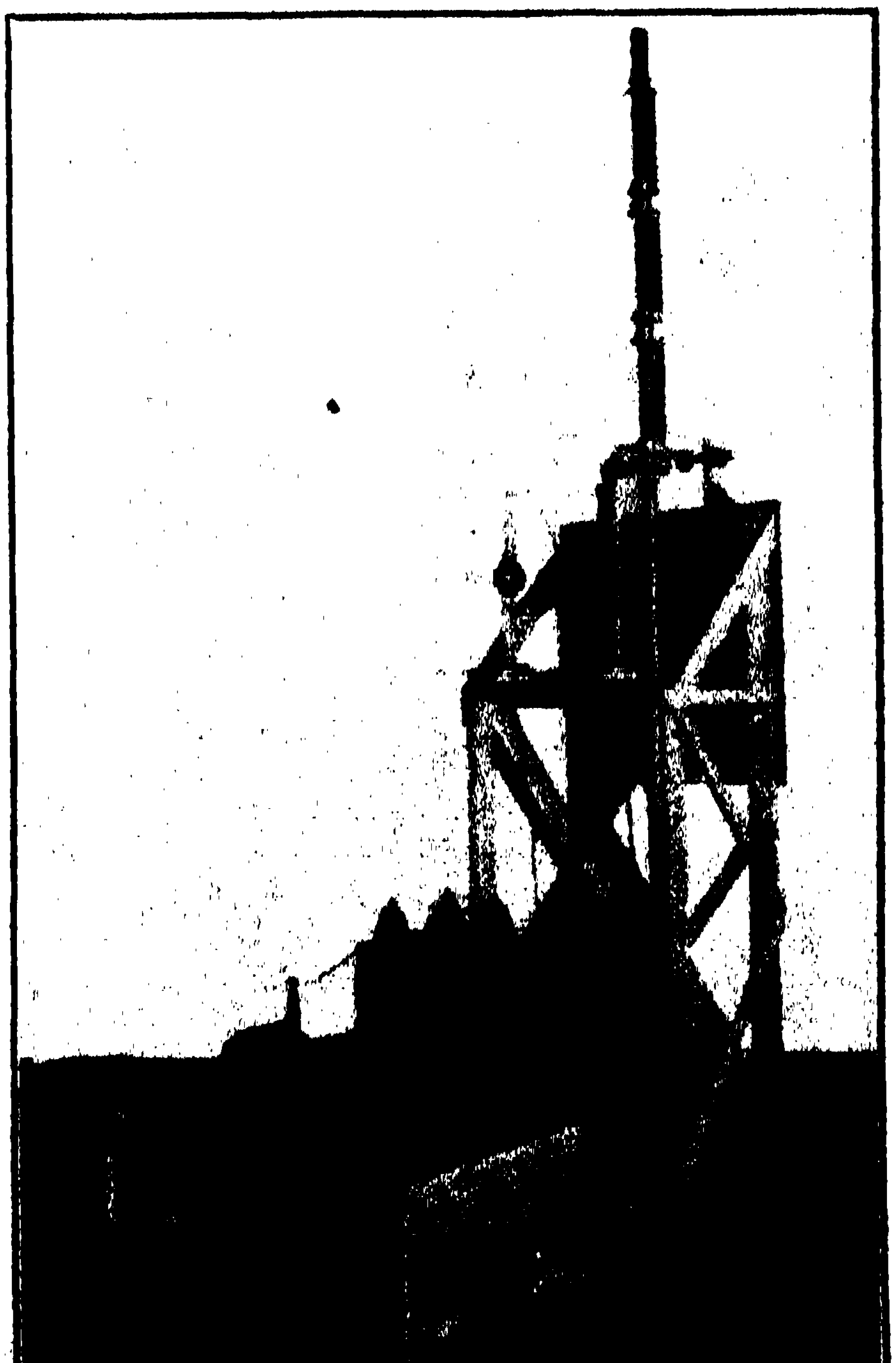
EQUIPMENT FOR MEASURING LIGHTNING VOLTAGES

By EDWARD BECK

WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY

BECAUSE of the great expansion of electric power systems during the past ten years, the disturbances caused by thunder-storms have assumed such importance that much effort is being expended on studies of their characteristics. The disturbances which are generated in the wires of a transmission line are exceedingly high voltages which may change at the rate of hundreds of thousands of volts in a millionth of a second. These voltages are known as transients. A knowledge of their exact characteristics is of great importance. In order to obtain it, it is necessary to record the transient in its entirety. As the transient may pass in a few millionths of a second and since the time of its occurrence can not be foretold, the making of such a record appears to be extremely difficult. As a matter of fact, it has been impossible until recently except in the laboratory under controlled conditions. Studies on actual transmission lines during their normal operation have been made possible by the cathode ray oscillograph developed by Dr. Harold Norinder, a Swedish scientist and a consulting engineer for the Westinghouse Electric and Manufacturing Company, who has the distinction of being the first to make records of lightning transients on transmission lines.

The Norinder cathode ray oscillograph makes a record on a photographic film of the entire transient disturbance from its very beginning to its end. As we are dealing with periods of time measured in millionths of a second, the action of the oscillograph must be extremely rapid. The ordinary instruments with mechanical moving parts are too slow in responding because of the inertia of their moving parts. The cathode ray oscillograph has for its moving element a beam of electrons whose inertia is practically zero. This electron beam impinges on a photographic film which it affects in the same manner as light. The electron stream, or cathode ray as it is commonly called, is deflected by a system of electrostatic plates coupled to the transmission line. Abnormal voltages occurring on the transmission line are instantaneously communicated to these plates which im-

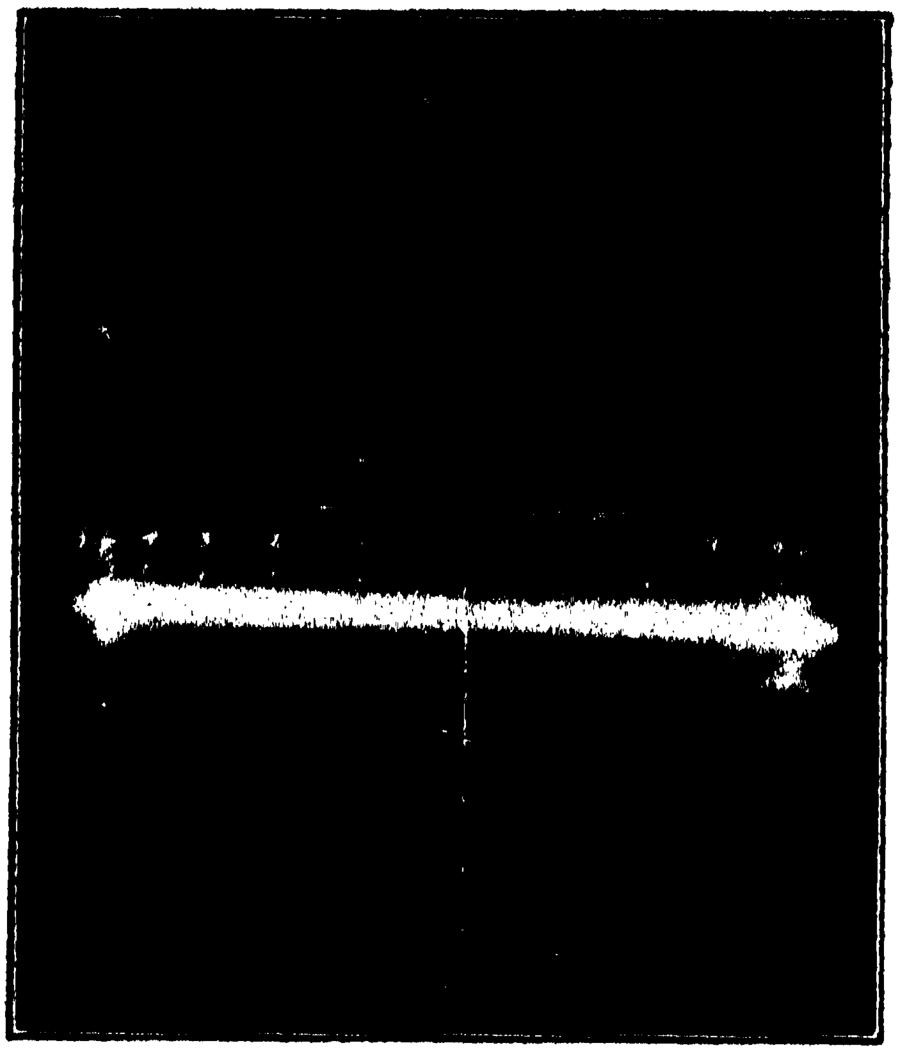


HIGH VOLTAGE SOURCE FOR GENERATION OF CATHODE BEAM

REAR VIEW, SHOWING TRANSFORMERS, CONDENSERS AND RECTIFIER TUBES.

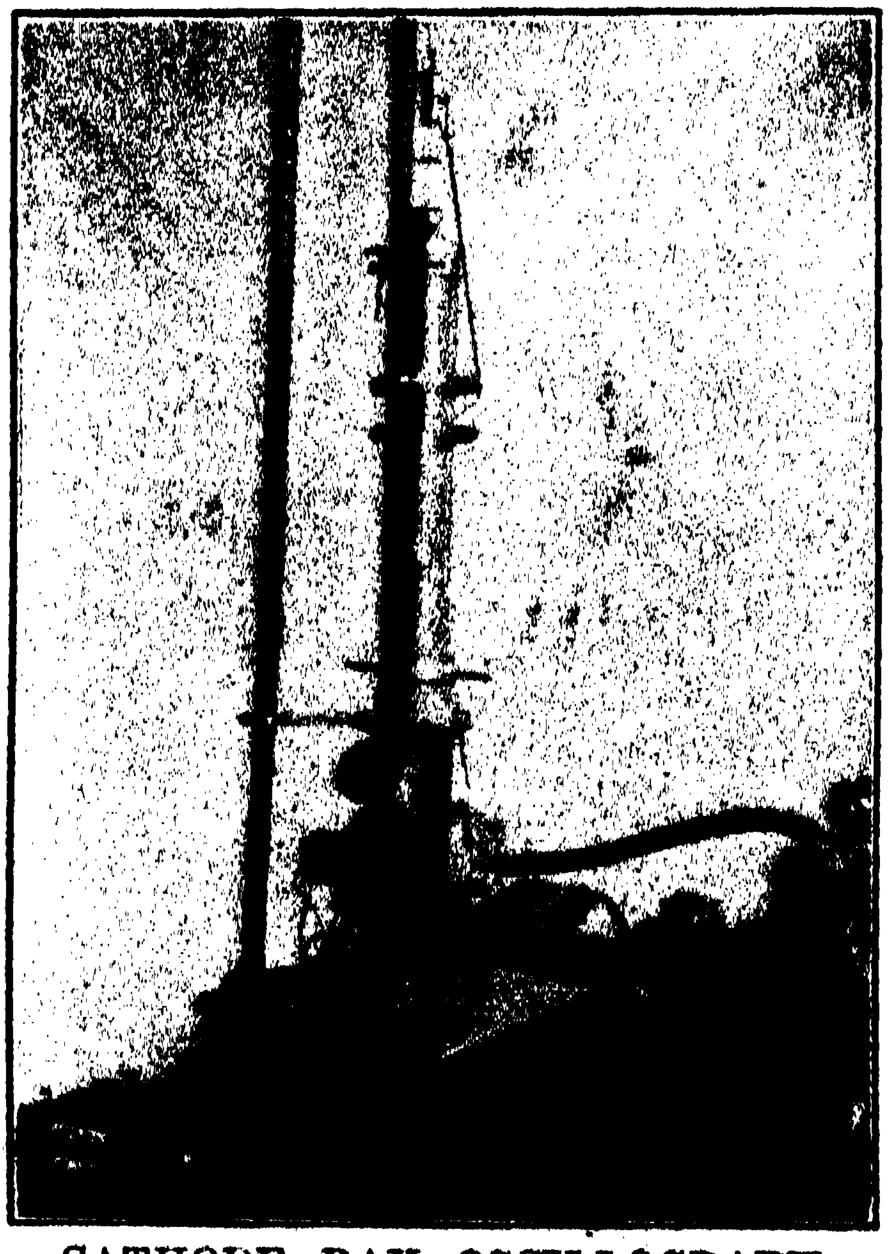
mediately exert a force on the cathode beam. Since it has no inertia, it immediately is deflected, thereby drawing a line on the photographic film, thus making a permanent record of the lightning disturbance.

The complete cathode ray oscillograph is about seven feet long and weighs approximately two hundred pounds. It may appear strange that an instrument of these proportions will make such delicate measurements; nevertheless it is a fact that it will respond with the greatest degree of sensitivity to the most rapidly changing phenomena. In order to operate the instrument, it is necessary to produce inside of it this beam of electrons. This is done by applying a high unidirectional voltage between a cathode located at the extreme top of the instrument and an anode slightly below the cathode. The electron stream generated at the cathode passes through a small hole in the anode and continues to the photographic film at the bottom of the oscillograph. On its way to the film, the beam passes between a system of electrostatic plates whose fields of force are determined by the lightning disturbance. A cathode beam may be produced only in an extremely low gas pressure. It is therefore necessary to exhaust the inside of the oscillograph to a pressure which is only about 1/200,000th of the outside air. To procure this low pressure and to maintain it in the oscillograph requires a highly efficient system of vacuum pumps. The pumping system is one of the most important accessories to the oscillograph. Without a reliable one, the instrument may fail to work at critical moments. Generally, two stages of pumps are used, the first a so-called rough pump which will produce a fairly low pressure when exhausting into the open air. The second stage is a Holweck high vacuum pump which exhausts into the low pressure created by the first pump.



RECORD OF A TRANSIENT ON A TRANSMISSION LINE

MADE BY MEANS OF A CATHODE RAY OSCILLOGRAPH. NOTE THAT ONE SWING ACROSS THE FILM REPRESENTS A TIME INTERVAL OF ONLY 11.2 MILLIONTHS OF A SECOND.

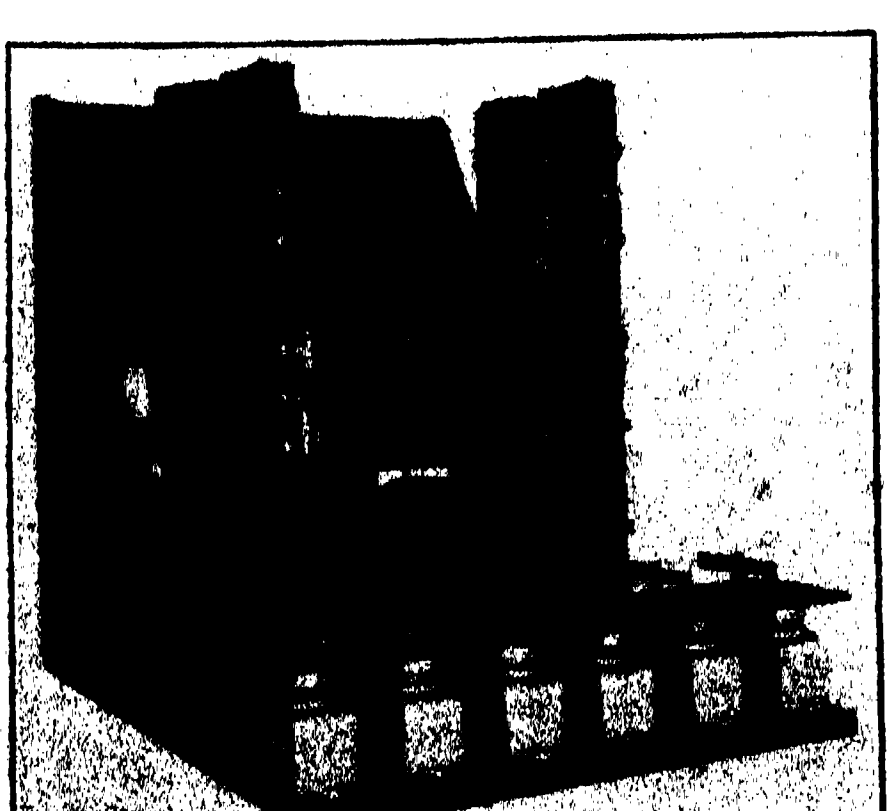


CATHODE RAY OSCILLOGRAPH

USED TO SECURE LIGHTNING RECORDS. THIS IS THE FIRST INSTRUMENT DEVELOPED TO GIVE COMPLETE AUTOMATIC RECORDS OF TRANSIENTS ON ELECTRIC SYSTEMS.

With the oscillograph and the proper pumping system, there is still required a source of high unidirectional voltage to generate the cathode stream. This voltage must be of the order of 30,000 to 60,000 volts, and must be uniform. It is obtained by means of transformers and high voltage rectifier tubes. The current drawn from this source is of the order of a fraction of a milliampere.

In order to obtain a clear record of these transients, showing the time durations which are involved, it is necessary to have a timing axis appear on the film. For relatively slow phenomena, this axis may be secured by rotating the film on a cylindrical drum. The drum used has a peripheral speed of about 12,000 feet per minute. For the very rapid transients, much higher speeds are necessary. These can not be obtained by mechanical means. For this purpose, the film is left stationary, and the electron beam is caused to travel back and forth across the film at a predetermined rate, usually by means of a high frequency oscillator which impresses a deflecting voltage on the beam at right angles to the system producing the voltage deflection. The oscillator used for this purpose is very similar to the oscillators used in radio practice. Its frequency is readily adjustable between wide limits, and by its use the current scale may be accurately set.



OSCILLATOR FOR TIMING AXIS
REAR VIEW.

INTERIOR OF A FIELD STATION

The equipment as described above is being used by the Westinghouse Company in some field tests by which much valuable data on lightning disturbances are being secured. Two installations have been made in the Tennessee Mountains on a 154,000 volt transmission line of the Aluminum Company of America. Besides the cathode ray oscillograph, which is the most important device used in these investigations, there are employed also other instruments to shed further light on the mysterious ways of lightning. Among these instruments are klydonographs, osisos, cameras and alarm circuits.

The klydonograph is an instrument which will record the maximum transient voltage occurring on a transmission line without, however, exposing any details as to its shape or duration. Until the advent of the cathode ray oscillograph, the klydonograph was the

most important instrument for investigation of lightning disturbances on transmission lines. Now it supplements the data obtained by the oscillograph by measuring the surge voltages occurring at different points along the transmission lines being investigated.

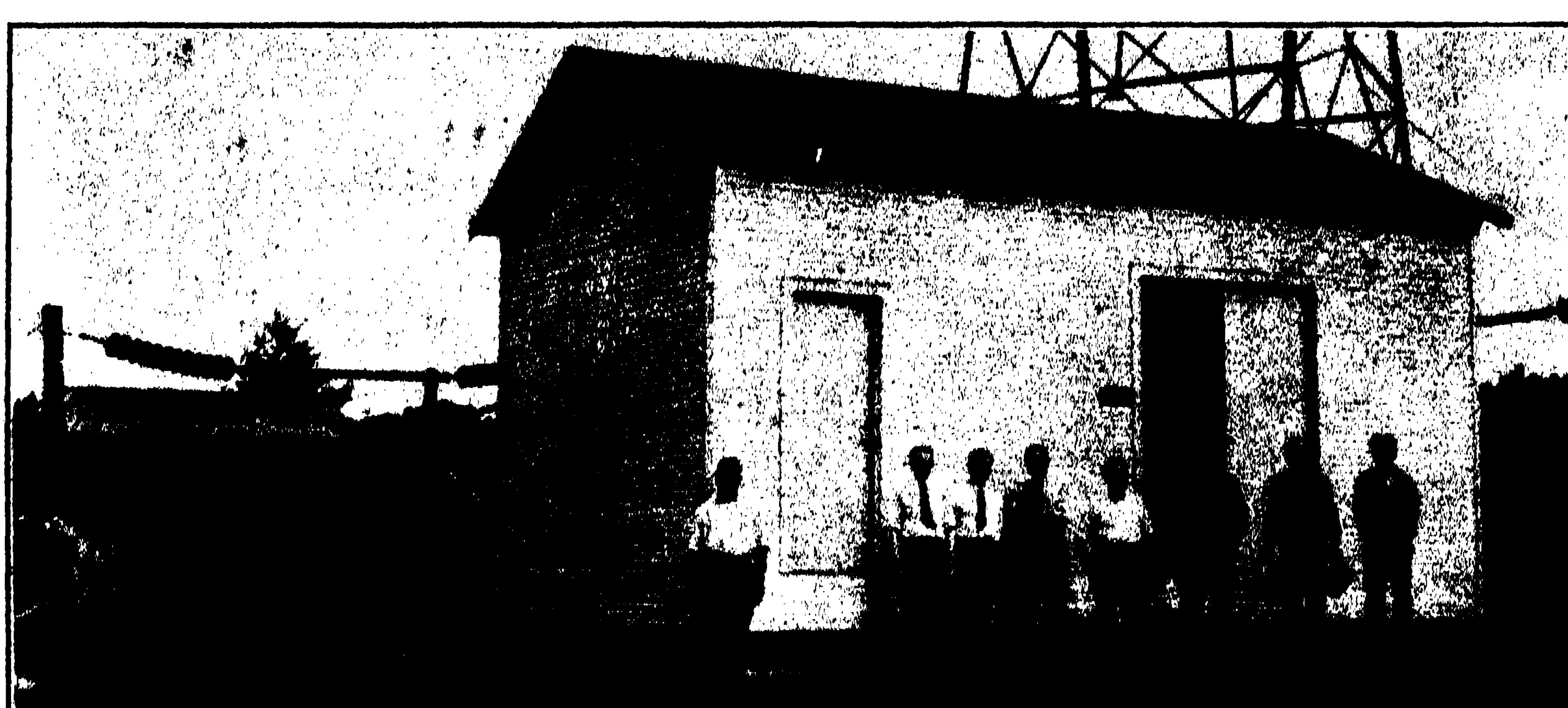
The osiso is a small oscillograph used for the recording of voltages or currents. In the lightning test it is used to locate the position of the lightning stroke. It is accomplished by measuring the time interval between the lightning stroke and the arrival of the thunder noise at the observation station. Microphones translate the noise of the thunder into electric currents which are recorded on the osiso. The time which elapses between the lightning stroke and the thunder is shown by the interval between the recording of the electrical disturbance and the recording of the thunder noise.

Further information about the lightning stroke is secured by means of a special camera which will photograph the entire horizon at once. A lightning stroke occurring anywhere above the horizon will record its appearance on a photographic plate. In conjunction with the data obtained with the cathode ray oscillograph, it is hoped that some relation will be found between the various characteristic lightning strokes, their location relative to the transmission lines, and the disturbances which they cause on these lines.

Radio receiving sets and a special form of transient relay which rings a bell are employed to announce the approach of a storm. When such an alarm is received, all the apparatus is put into operation and the oscillograph tested so that it may be ready when the storm arrives.

There are many details in connection with the field laboratories which are of interest, such as the special measures which are involved in the construction of the laboratories, the obtaining of adequate supplies of power and water, and communication between stations. The objects of most interest, however, are the newly developed pieces of equipment such as have been described in the foregoing paragraphs.

With this equipment now available, the intensive studies being made of lightning phenomena will within the next few years clear up many of the unknown factors involved in lightning disturbances.



ONE OF THE FIELD LABORATORIES EMPLOYING OSCILLOGRAPH EQUIPMENT

THE PROGRESS OF SCIENCE

THE CONVOCATION WEEK MEETING IN NEW YORK

THE meetings of the American Association for the Advancement of Science and of sixty-four associated scientific societies held during the week following Christmas fulfilled all the predictions made by the president, Dr. Henry Fairfield Osborn, in the article printed in the last number of this magazine. It indeed surpassed them, for by common consent there has not hitherto been held in this country and perhaps not elsewhere a meeting at which so many contributions were presented by so many scientific men, or at which the arrangements for their scientific programs and their entertainment were so complete.

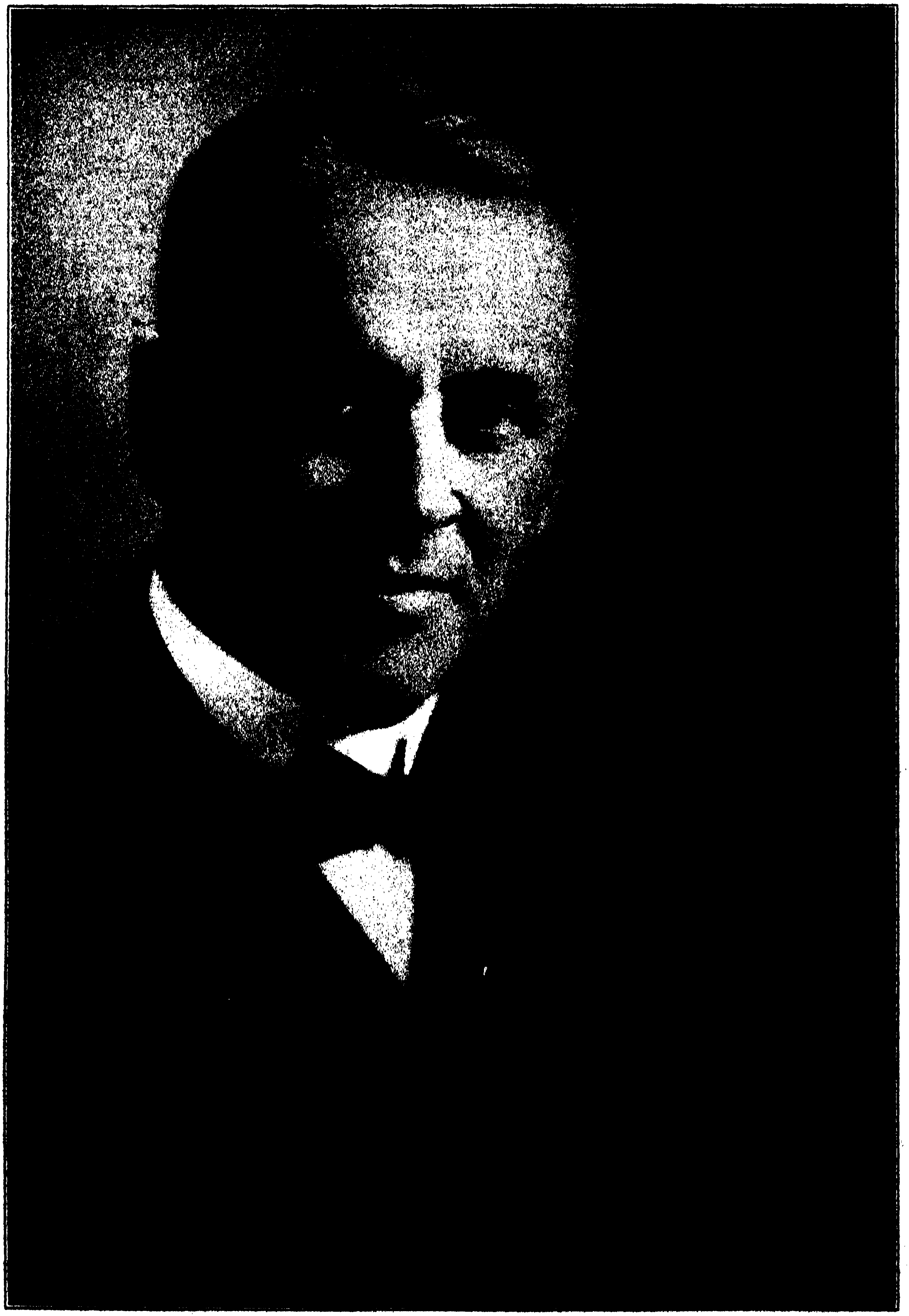
The approximate figures are 2,200 papers and addresses presented by 1,900 different individuals at 250 sessions. The registration was about 4,000; the total attendance perhaps 50 per cent. larger. The printed program extended to 350 pages; an examination of the titles indicates how completely the whole field of modern science was covered by the research papers and by the addresses and sessions of general interest.

A special feature of the meeting was the series of lectures arranged by President Osborn at the American Museum of Natural History, followed every evening by a reception with the opening of the whole museum on the first evening and of the halls appropriate to the lectures on subsequent evenings. The lectures in the evening and in the late afternoon were by the most distinguished American men of science—the retiring president of the association, Professor A. A. Noyes, on chemistry; Professor Charles P. Berkey, on Asiatic exploration; Professor Arthur H. Compton, on physics; Professor William Morton Wheeler, on biology; Professor Harlow Shapley, on astronomy; Professor Franz Boas, on anthropology; Professor Bailey Willis, on geology, and others. Two of these addresses are printed in the present issue of the MONTHLY, which hopes to have the privilege of printing others. There were also lectures by Professor G. H. Hardy, of Oxford, and by Professor H. H. Turner, of the same university, the latter having been sent as a special representative from the British Association.

Columbia University and Teachers College entertained a large proportion of the section meetings and the special societies, each of which had its own program, including many sessions planned to be of general interest to all scientific men and indeed to the wider public which is coming to realize the dominant place of science in modern civilization. The only difficulty was the conflicts. If all the papers had been given in succession at the rate of seven a day the meeting would have lasted for a year. At Columbia University was the scientific exhibit which provided a continuous *conversazione* through the week.

In addition to Columbia University and the American Museum of Natural History some forty other scientific and educational institutions of the city acted as hosts, placing their facilities at the disposal of visiting scientific men for meetings or for visits. Especially to be mentioned are the reception at the Metropolitan Museum of Art and the Philharmonic Symphony Concert in Carnegie Hall. At the latter President Osborn, in thanking the conductor, Mr. Mengelberg, said that perhaps never before had so many scientific men been assembled in one audience.

It was the fifth meeting of the American Association for the Advancement of Science in New York and the third of



DR. ROBERT A. MILLIKAN

the convocation week meetings held after Christmas in cooperation with the associated scientific societies. During the more than fifty years of its history in the course of the last century the association met only once in New York, when in 1887 Dr. S. P. Langley, secretary of the Smithsonian Institution, was president. In 1900 the meeting, still in summer, was under the presidency of R. S. Woodward, then professor in Columbia University and later president of the Carnegie Institution. There were then only 1,200 members of the association; the increase to the present 17,500 was in large measure due to the action taken at that meeting in establishing *Science* as the official journal of the association. The convocation week meeting of 1906 was held in December under the presidency of Dr. William H. Welch, long dean of the medical school of the Johns Hopkins University, leader in the development of scientific medicine. Ten years later Dr. Charles R. Van Hise, the distinguished geologist, president of the University of Wisconsin, presided. At about that time it was arranged that meetings should be held once in twelve years in New York and in the intervening four-year periods in Washington or in Chicago. These are the larger convocation week meetings in which the executive officers are elected for the ensuing four-year period.

At the recent meeting Professor Burton E. Livingston, professor of physiological botany at the Johns Hopkins University, whose conduct of the association during the past eight years has met the unanimous approval of American men of science, was reelected permanent secretary. Dr. Frank R. Lillie, professor of embryology at the University of Chicago, was elected general secretary, and secretaries were elected for the fifteen sections. Distinguished scientific men to serve for one year were elected as chairmen of the sections and vice-presidents of the association.

Full accounts of the meeting, prepared by the permanent secretary of the association with the cooperation of the secretaries of the sections and of the associated societies, will be published in the issues of *Science* for January 25 and February 1. Copies may be obtained without charge by members of the association who do not receive the journal regularly, and by others who remit the cost, by addressing the office of the permanent secretary of the association in the Smithsonian Institution Building, Washington.

THE PRESIDENT OF THE AMERICAN ASSOCIATION

The distinguished line of succession in the presidency of the American Association was continued by the election of Dr. Robert A. Millikan to follow Dr. Henry Fairfield Osborn. It was an open secret among scientific men that when it came the turn to elect a physicist it would be Dr. Millikan. The nominating mail ballot from all members of the association was nearly unanimous except in the case of those who did not understand that there is a policy of alternation between the physical and natural sciences or who cast a complimentary ballot for a biologist.

Dr. Millikan is one of the few American men of science who has continued to carry forward research of the highest order while at the same time constantly engaged in public service for science. For example, he came from the Pacific coast to attend the meeting of the National Academy at the end of November and again in December to attend the meeting of the American Association. He is foreign secretary of the National Academy, vice-chairman of the National Research Council and the American member of the committee on intellectual cooperation of the League of

RECIPIENTS OF NOBEL PRIZES

Photograph taken at Stockholm at the time of the conferring of the Nobel prizes. On the left is Dr. Adolph Windhaus, professor in the University of Göttingen, and, on the right, Dr. Heinrich Wieland, professor in the University of Munich. The awards for 1927 and 1928 were made to both for their distinguished work in physiological chemistry. In the center is Mme. Sigrid Undset, the Norwegian, who received the prize in literature.

DR. OLIVER KAMM

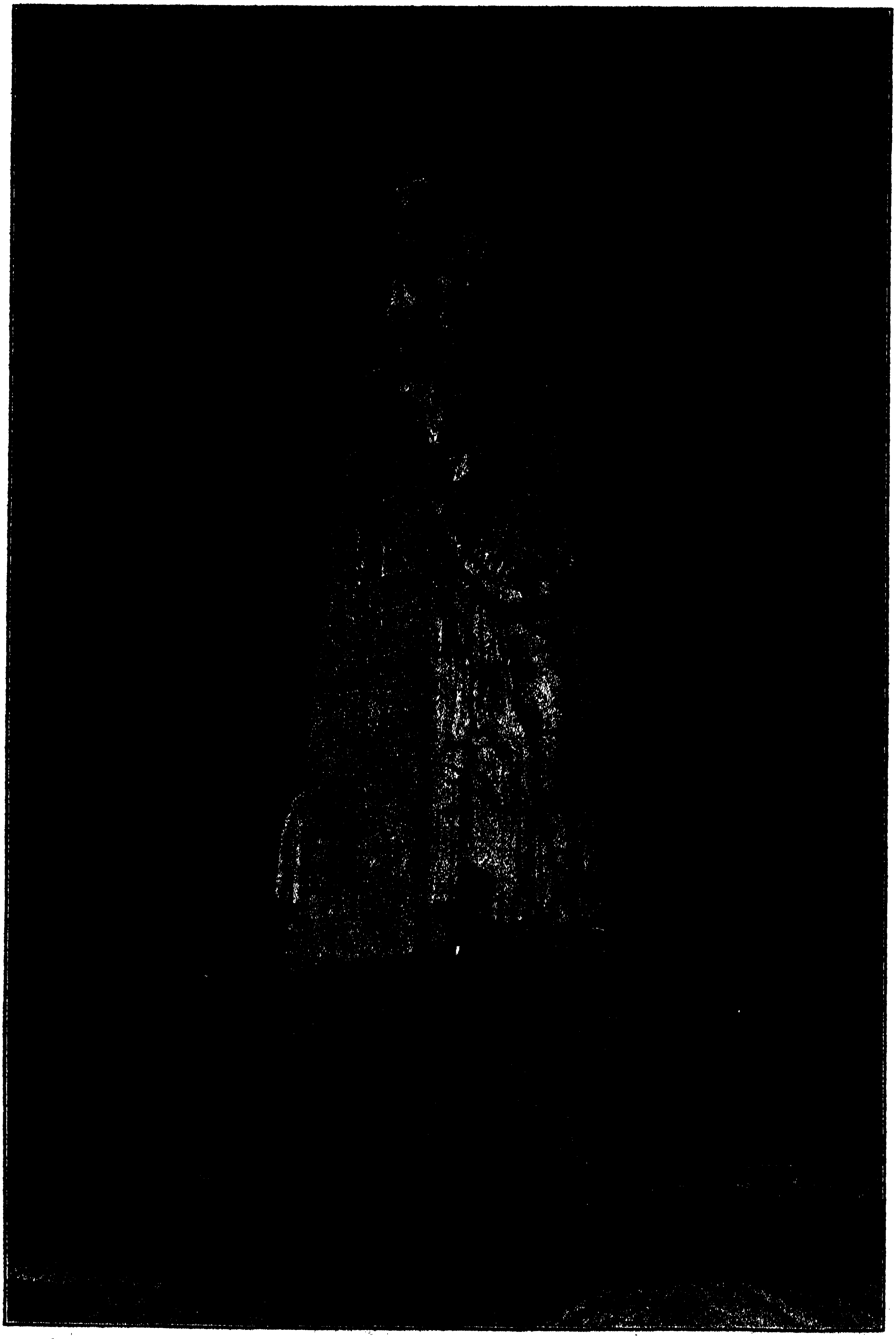
RESEARCH DIRECTOR OF MESSRS. PARKE, DAVIS AND COMPANY, THE RECIPIENT OF THE THOUSAND DOLLAR PRIZE OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE. THE AWARD WAS MADE TO DR. KAMM FOR HIS PAPER, ENTITLED, "HORMONES FROM THE PITUITARY GLAND," WHICH HE PRESENTED BEFORE THE SECTION OF CHEMISTRY OF THE ASSOCIATION.

Nations. His great executive work has been in establishing with Dr. George Ellery Hale the California Institute of Technology as one of the world's chief centers of scientific research. The institute has provided two of the three last presidents of the American Association and it may provide the next two. The California Institute has no president, Dr. Millikan being chairman of the executive council as well as director of the Norman Bridge laboratory of physics.

Dr. Millikan is the author of an even dozen books, alone or in cooperation with his colleagues in physics, covering a wide field from the electron to the relation between science and religion. The best known of his researches, the earlier of which won him the rare honor of a Nobel prize, are probably the following:

(1) The isolation and measurement of the electrons, which work furnished the most direct and complete demonstration yet found of the atomic structure of electricity, and makes it possible to count the number of molecules in any weight of any simple substance with as much certainty as can be attained in counting the inhabitants of a city.

(2) The direct photoelectric determi-



MEMORIAL TO LOUIS PASTEUR

nation of the fundamental radiation constant known as Planck's h, which constituted the first direct experimental establishment of the validity of an equation which Einstein had suggested in 1905, and which has now become scarcely second in importance in the electromagnetic theory of the equations of Maxwell.

(3) The study of Brownian movements in gases constituted one of the strongest links in the chain of evidence which finally silenced all opposition to the atomic and kinetic theory of matter—an opposition actively led by Ostwald and formally renounced by him about 1915, with specific reference to the studies of Dr. Millikan and his pupils.

(4) The work on the extension of the ultra-violet spectrum reported in a series of papers from 1920 to 1923 pushed the limits of explored frequencies in the ultra-violet two octavos farther down. This study completed the work begun by Moseley in establishing the order of progression or of evolution of the elements by means of the only completely reliable agency now available for determining that order, namely, the character of the radiation emitted by the constituent electrons within the atom.

(5) The discovery reported in 1923 of "The law of motion of a particle falling toward the earth after it enters the earth's atmosphere" settles definitely one of the historic problems of the kinetic theory which has been the subject of controversy among physicists for seventy-five years.

(6) The experimental study, with Dr. I. S. Bowen, of the spectroscopic properties of light atoms in all stages of "stripping," *i.e.*, when either completely stripped, or partially stripped, of their valence electrons. The spectroscopic laws discovered through this study was one of two equally potent causes leading to the introduction by Uhlenbeck and Goudsmit in 1925 of the new and fundamental conception of "the spinning electron."

(7) The discovery of the laws governing the extraction of electrons from metals by fields alone furnished the first direct experimental proof that the electrons in metals do not share appreciably at ordinary temperatures in the motions of thermal agitation, but do begin to share at sufficiently high temperatures. It begins to clear up the mysteries surrounding the nature of metallic conduction.

(8) The study of the nature and properties of cosmic rays brought to light in 1924 the best evidence yet found for the existence of a very high frequency radiation of cosmic origin, which appears to shoot through space uniformly in all directions.

MEMORIAL TO LOUIS PASTEUR IN CHICAGO

A MEMORIAL to Louis Pasteur was dedicated Saturday, October 27, 1928, in Grant Park, Chicago. The memorial is a monument twenty-eight feet high, and consists of an ornamental shaft upon which is placed a bust of the great scientist which is an excellent likeness of the man. The base is twenty-two by twenty-six feet, and both base and monument are in Carrara marble.

The memorial is located at the west end of the Field Museum of Natural History, and therefore bears an appropriate relation to the great museum and the accomplishments of a great naturalist.

The monument was designed and executed by Leon Hermant, the celebrated sculptor, and Mr. Edward H. Bennett had charge of the architectural features including the landscaping and constructing the foundation.

The memorial was built with funds obtained by popular subscription from

Bashford Dean
1925.

To Prof. J. McKeen Cattell, with great esteem and appreciation

approximately one thousand contributors, including members of the medical profession, members of Chicago French societies and other organizations as well as many individuals.

On the back of the shaft is a bronze plate which carries this inscription:

Louis Pasteur
1822–1895

Benefactor of Industries, Revealer of Mysteries of Disease of Man and Animals and Deviser of Methods for Its Control, Whose Discoveries Have Lessened Suffering and Prolonged Life and Added Immeasurably to the Comfort, Security and Dominion of Man

At the dedicatory exercises Dr. Frank Billings, the chairman of the Pasteur Memorial Committee, presided. Professor Ludvig Hektoen, of the University of Chicago, made an address on Pasteur. M. Paul Claudel, ambassador of France, spoke in behalf of the French people. Mlle. Claudel, the daughter of the French ambassador, unveiled the monument, and finally the monument was presented to the commissioners of the South Parks of Chicago by Dr. Billings and was accepted for preservation by Mr. Edward J. Kelly, the president of the South Parks.

BASHFORD DEAN

BASHFORD DEAN, late professor of zoology in Columbia University, honorary curator of fishes in the American Museum of Natural History, former curator of arms and armor in and a trustee of the Metropolitan Museum of Art, died at Battle Creek, Michigan, December 6, 1928, aged sixty-one years.

Dr. Dean's interest in the two subjects, armor and fishes, in each of which he became a world authority, was manifest early in life—at or before the age of seven. At the age of nineteen he graduated from the College of the City of New York. He then entered Columbia University, where he studied fossil fishes under Dr. J. S. Newberry, and whence he graduated with the Ph.D. degree in 1890, his dissertation being entitled "Pineal Fontanelle of Placoderm and Catfish."

In 1886, Dean was appointed tutor in natural history in the College of the City of New York. In 1891 he was made instructor, in 1896 adjunct professor, and in 1903 professor of vertebrate zoology in Columbia University. During these years he made extensive investigations for the U. S. Fish Commission into the methods of artificial oyster culture in southwest Europe and in Japan, becoming an authority on this subject.

With the appointment to Columbia, Dean began researches in the paleontology, anatomy and embryology of fishes which made him the acknowledged leader in America in these branches of ichthyology. Particularly he extended the work of Newberry on the Devonian armored shark-like vertebrates, and made brilliant embryological studies of three American Ganoids—the bowfin, garpike and sturgeon. Turning to the lower marine vertebrates, he made equally brilliant studies of the embryology of the hagfishes and the silver sharks. Unfortunately he left unfinished similar studies on the embryos of the Port Jackson and of the Japanese frilled sharks. His best-known single work is "Fishes, Living and Fossil" (1905).

As curator of fossil fishes and afterwards of ichthyology in the American Museum covering the period 1903–1910, Dean planned and installed the habitat groups of fossil fishes and of living Ganoids and other fishes in the American Museum which set new standards for museum exhibits of fishes. About this time he began the final bibliographical work which resulted in the publication of the great three-volume "Bibliography of Fishes" (1916, 1917, 1923), by

the American Museum, for which he was awarded the D. G. Elliott medal in 1923.

In 1910, because of his eminence in zoology, Dean was made a Chevalier de la Légion d'honneur. Resigning his curatorship in the American Museum in this year, he was made curator of arms and armor in the Metropolitan Museum, and built up a collection there which to-day ranks fourth of all in the world, and unlike any other is arranged on a strictly evolutionary basis. When our country entered the World War, Dean volunteered for service and was commissioned major in the Ordnance Department. He studied conditions of trench warfare in Europe and engaged in extensive experiments for improving helmets and body armor when the sudden ending of the war came. His final work in the Metropolitan Museum, a "Bibliography of Arms and Armor," is nearly ready for the press.

Dr. Dean was an exceedingly brilliant and versatile man, who, despite the life-long handicap of frail health, wrought prodigiously. His outstanding characteristics were a devotion to science and a love of the beautiful in art. After his retirement he designed, built, and with his own hands decorated a large Gothic hall as an addition to his house at Riverdale, New York. In this he had begun the installation of his private collection of armor, when his call came.

THE SCIENTIFIC MONTHLY

MARCH, 1929

RECENT GEOLOGIC EXPLORATIONS IN CENTRAL ASIA[1]

By Dr. CHARLES P. BERKEY

COLUMBIA UNIVERSITY

THIS evening I want to introduce you to the continent of Asia, and to that end I propose to practice a little magic, an art not at all strange to the land I hope to have you see. Following the approved method of magicians I must tell first what is to happen, and then I shall expect every one to become convinced that it has been done.

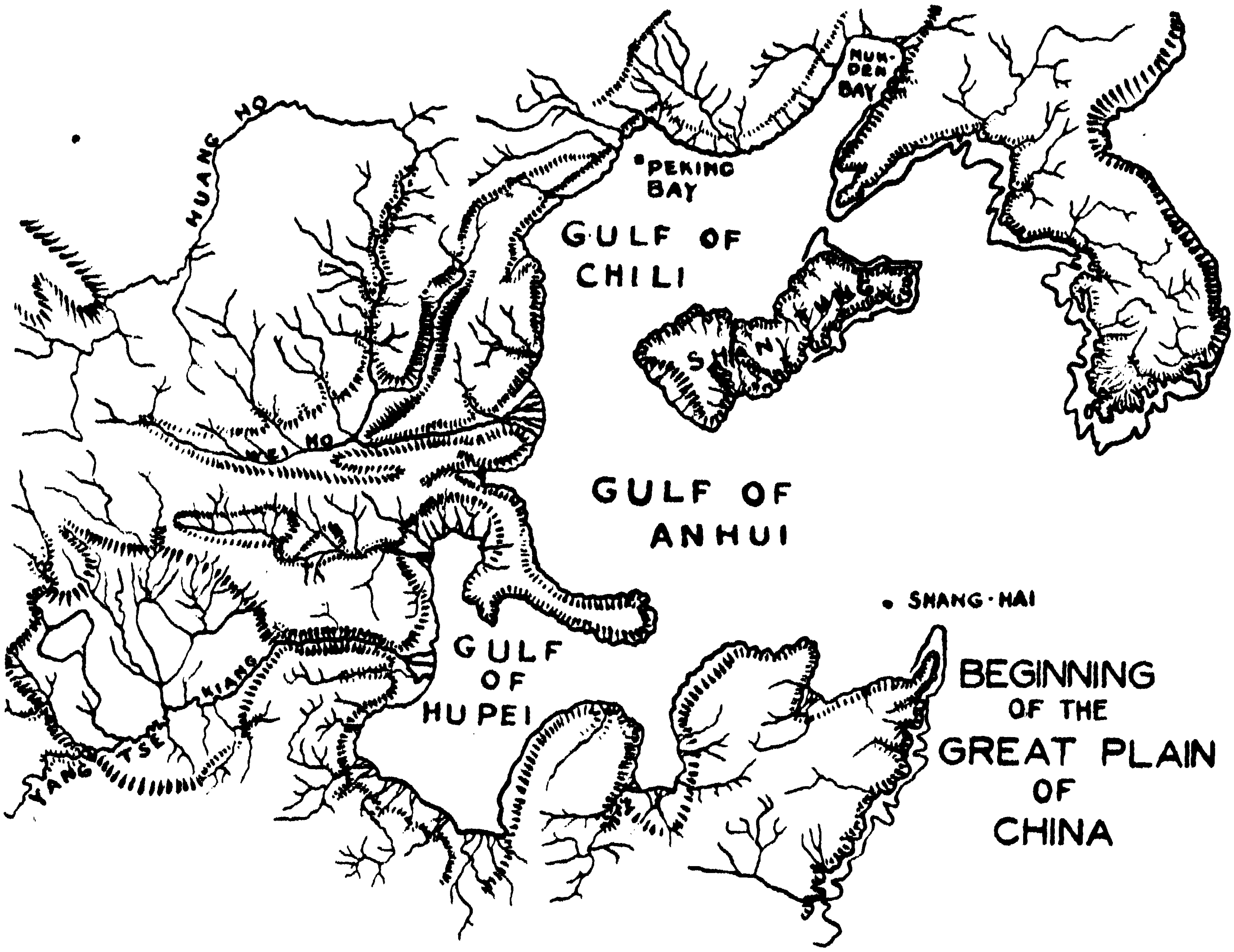
We shall all go together on a long journey. No one need make special preparation, for it will make no difference how fast we go or in what manner, just so by this means we may see the continent of Asia and begin our acquaintance with a fascinating and too-little-known portion of the earth.

Now let us be off. I shall act as conductor and describe the more significant features as we come to them. This is the most approved method in geology anyway, for it is comparatively easy to keep our bearings in that way, passing from the well known of our own home town to the little or entirely unknown and untried trails of strange lands.

At first the scenes are all familiar. The verdure-covered mountainous belt of the Highlands of the Hudson and the Catskills, with the Appalachian mountain ridges stretching away to the southward, are soon left behind. Then the Great Lakes, and next the enormously broad, monotonously level, unbelievably productive farm country of the Mississippi Valley rolls away for a thousand miles, rising ever so gradually westward until it merges imperceptibly into the Great Plains beyond. By and by even the seemingly interminable plains stop abruptly against the great natural barrier of the Rocky Mountain front, and the easy going is at an end. But one may mount this range as the airplanes do and thence continue for other hundreds of miles over one mountain range after another, with their alternating intermont parks and rich valleys, to a series of desert basins, beyond which lies the second great mountain barrier, formed by the imposing Sierra Nevada guarding the Pacific slope. Here again, however, it is but a simple matter for us to mount this last barrier and glide down over its long ragged western slopes to the level of the sea.

Although this looks like the end, our real journey has only begun. Here we must take ship and sail out through the Golden Gate, for the objective is across the seemingly boundless Pacific, on the other side of the earth. In less than a week one comes to islands that rise

[1] Address at the first general session of the New York meeting of the American Association for the Advancement of Science, given at the American Museum of Natural History on the evening of December 27, 1928.



—*From the American Museum of Natural History*

SKETCH MAP OF THE COAST LINE

AT THE BEGINNING STAGE OF THE GREAT PLAIN OF CHINA, BEFORE THE RIVERS HAD ACCOMPLISHED MUCH DEPOSITION OF SILT. PREPARED BY F. K. MORRIS.

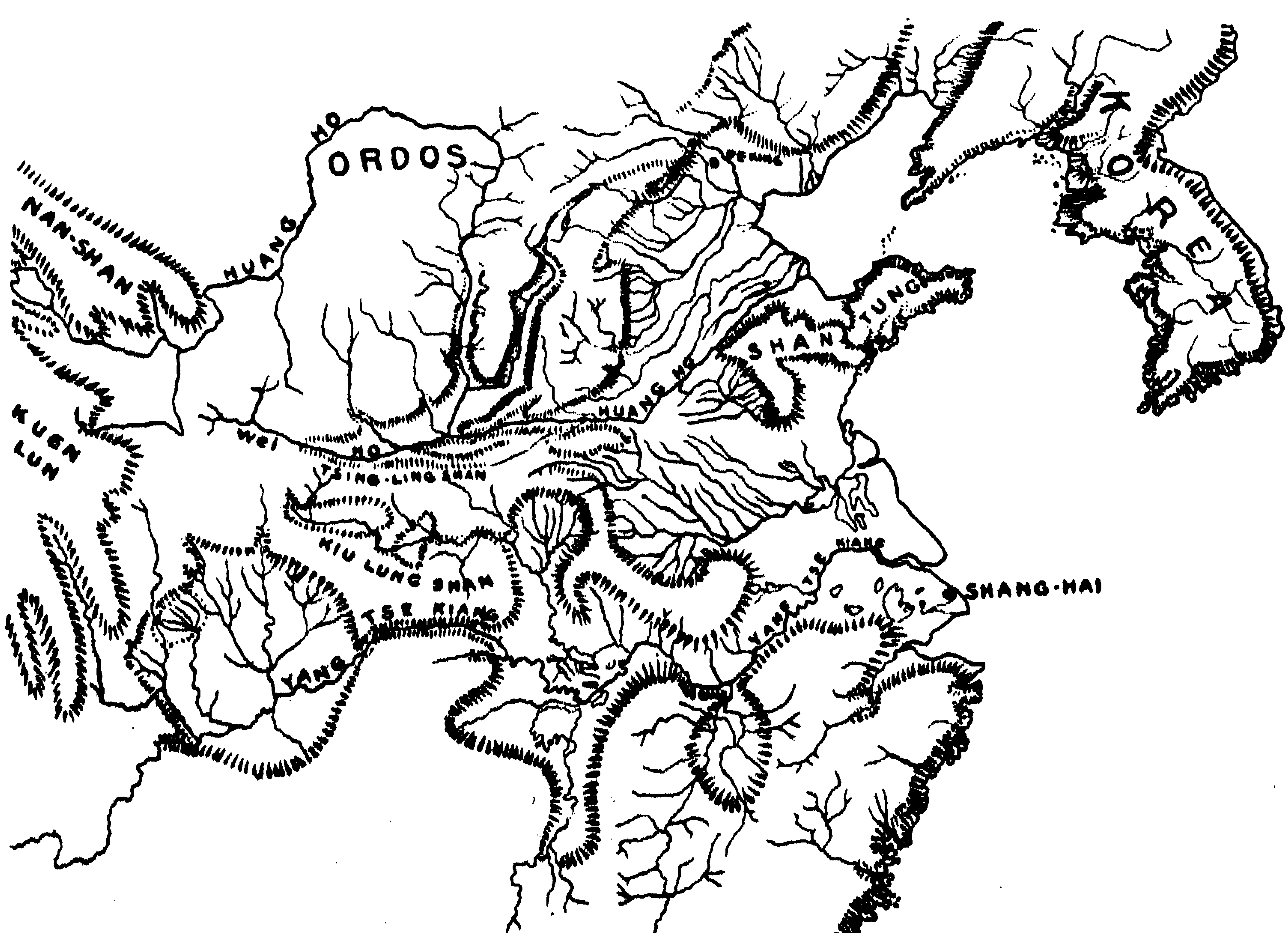
abruptly out of the sea as if they were mountains standing there. And so they are—enormous volcanic mountains built up on the ocean floor by the accumulation of lavas and other volcanic débris until they have reared their summits above the waters of the deep and reach far into the clouds. Here one may see volcanic activity in its most impressive form still operating, and a mountain still growing with the material erupted from the interior of the earth. These are the Hawaiian Islands, a virtual island paradise in the mid-Pacific.

In another two weeks one comes again to islands that appear as abruptly as the volcanoes of Hawaii. This time they are mountain ranges that have been drowned in the sea. They are more complex in their structure and history, much higher and much larger than those of Hawaii, but again they impress one chiefly with their great relief and ruggedness. These mountainous islands, with their terraced farm plots clinging to their lower slopes, we call Japan.

From Japan we sail through the inland seas between and around these drowned mountain-range islands into the China Sea, which separates Japan from the continent of Asia. For two days we may sail over waters as blue as the ocean affords, and then, as the ship plows its way toward Shanghai, the waters change color. By and by they have turned a dirty yellow—as yellow as waters can be. I knew, of course, as a boy that this was called the Yellow Sea,

but I supposed it was because the yellow races lived on its borders. Now I know that it is called the Yellow Sea because it is yellow. And the sea is yellow because of the enormous quantities of silt which the rivers of Asia carry down from the interior of the continent. The yellow dust, called loess, that has been swept out of the deserts by the wind is picked up again by the rivers and is carried out into the sea miles and miles before settling. When it does settle out it accumulates on the floor of the sea, little by little, time without end, one century after another, until ultimately the deposits build to the very surface of the sea. So places where the sea once stood become land which the rivers overflow and build up still more. This work the rivers of Asia have been doing for ages, pushing the borders of the land further and further out into the sea. They have actually built these lands that are known as the plains of China.

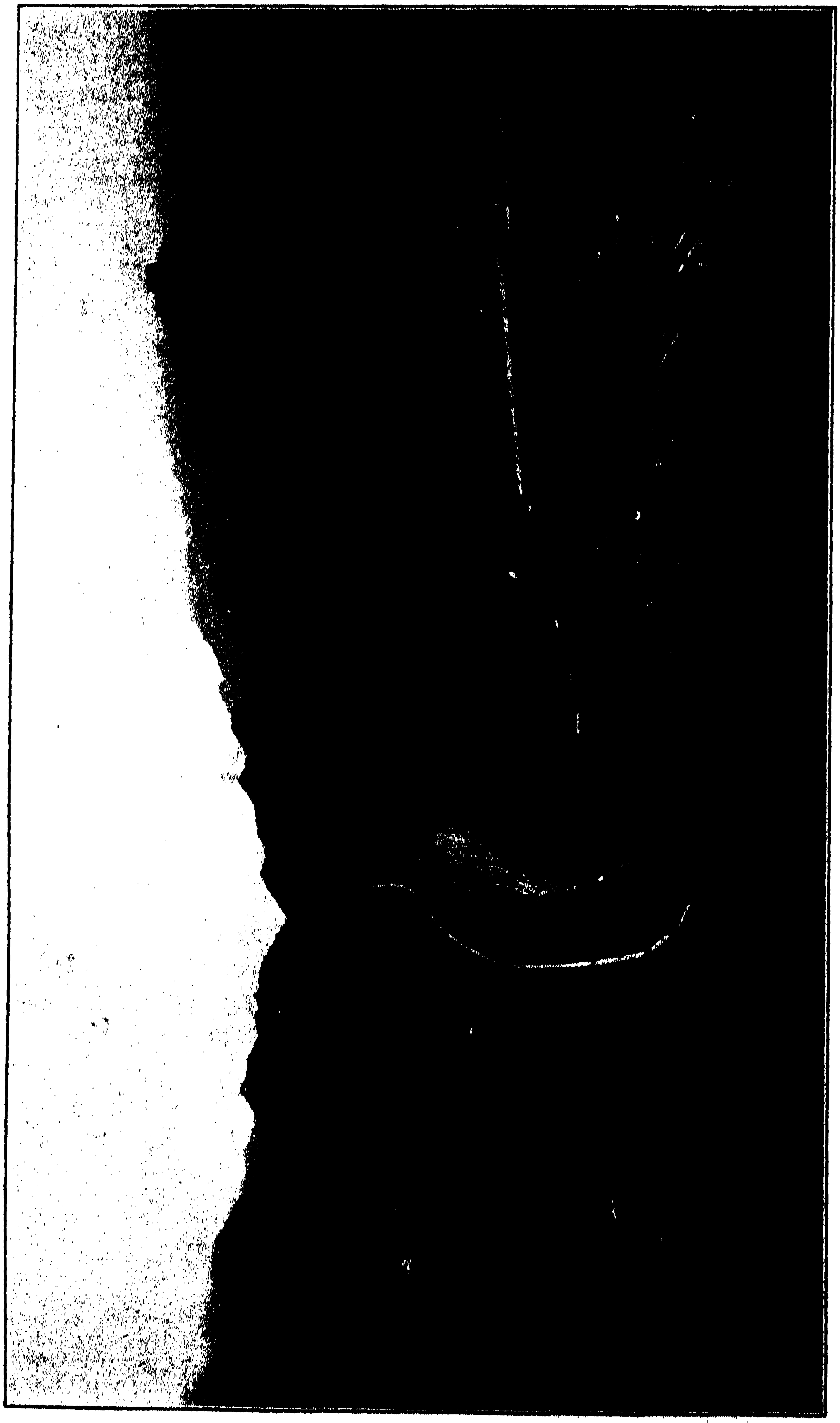
So, when one comes in sight of land again, it is just as different from the islands seen before as a land can be. That low dark streak on the horizon emerging from the haze hardly above the level of the sea itself is land—the first glimpse of the continent of Asia. This is the outer margin of the great plain of China. It is as flat and level as a floor, and so low-lying that one almost expects it to be inundated by the next tide or to be overflowed by the Yangtse River in flood season, ready to spread a new layer of silt over the face of the plain. Such things have happened year after year, literally for ages, making this one of the



—*From the American Museum of Natural History*

SKETCH MAP OF THE CHINA COAST TO-DAY

Showing the Great Plain which has been built up by the rivers coming from the interior. (Compare with sketch map showing beginning stage.) Prepared by F. K. Morris.



—*Photo by Roy Chapman Andrews*

THE GREAT CHINESE WALL
WHICH FORTIFIES THE MOUNTAIN BARRIER BACK OF PEKING.

richest and most extensive alluvial plains known on the face of the earth.

Pushing on from Shanghai, one sees only this monotonous plain, but in the course of time he comes to hills that emerge as abruptly from the plain as the islands of Hawaii or Japan did out of the sea. That is because they once were islands themselves, standing in the sea, and the plain that now surrounds them has been built by the rivers with their loads of silt deposited in the surrounding waters of a former time, just as is now happening out in the sea beyond Shanghai. Therefore one may now walk over to the hill that once was an island instead of swimming to it, as he used to do.

So one continues his journey over low-lying country northward to the Shantung peninsula. This fine province with its sacred mountain, Tai Shan, was once a mountainous island lying out in the sea just like the islands of Japan. But the Yellow River filled up the depths of the sea and built this plain around it, adding it all to the continent of Asia.

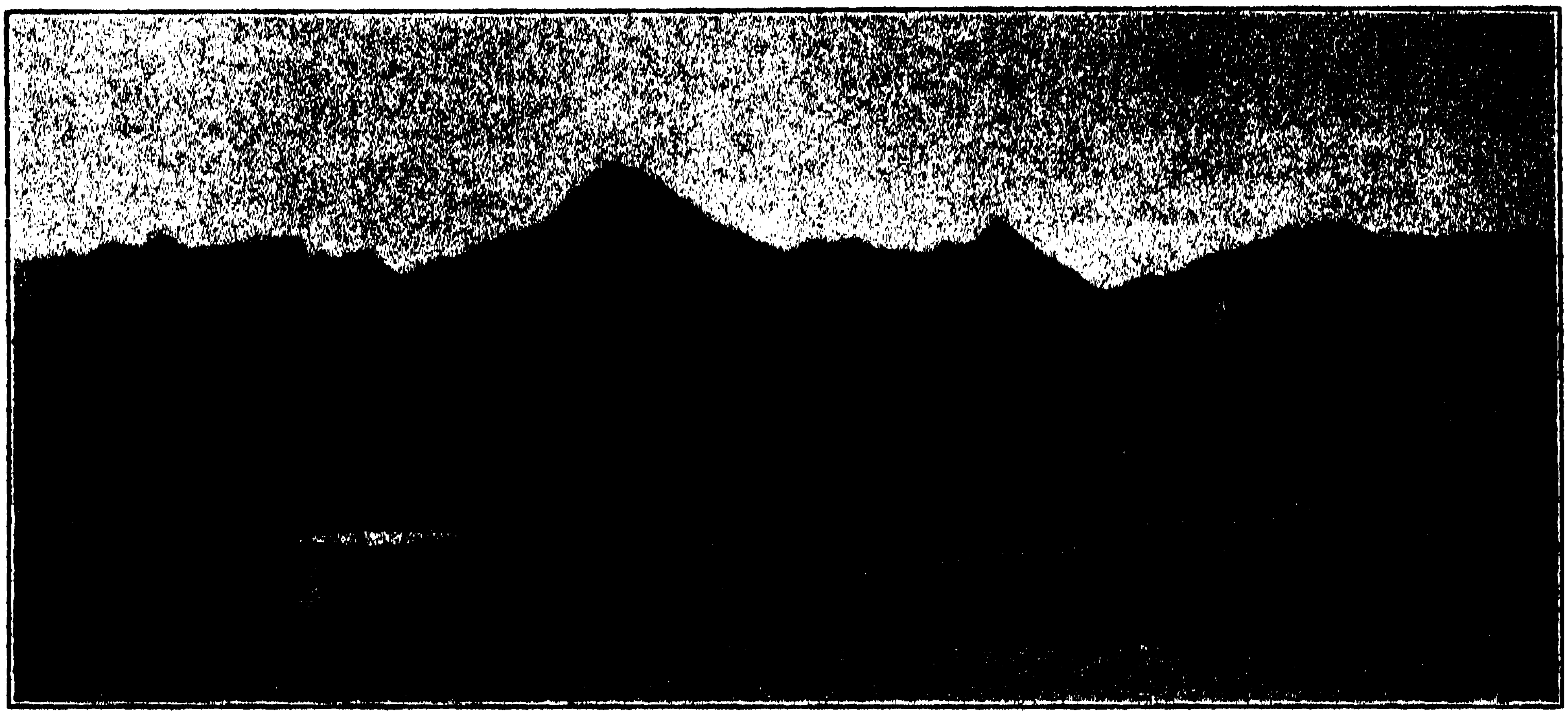
Once over this partially buried mountain range one comes down to the plain again, crosses the Yellow River and is off to Tientsin and inland to Peking, the old capital of China, from which point one must make a new start. Now after a journey that has taken two days one is astonished to find that he is still on the Great Plain of China and only a hundred and fifty feet above sea-level, although he has journeyed nearly a thousand miles.

But if one goes beyond Peking only an hour's journey, a great change takes place; a high mountain range rises almost as abruptly as a monster wall. This is the natural protective barrier for the people of the plain. To go further into Asia one must find one of the very few passes which penetrate this exceedingly rugged and difficult range. Here it is that the Chinese have built their Great Wall as an extra protective measure. We shall take Nan K'ou Pass, the only one within reach, and the same through which the hordes of Mongol invaders from Central Asia came down in ancient times under Genghis Khan, "The Emperor of all Men," when they overran China.

This time, after reaching the head of the pass two thousand feet above the plain, one does not come down again, but continues westward almost on a level with the mountains as if on a great terrace, a half day's journey farther inland to Kalgan, the last city on the very borders of the unknown. Here one faces a second great mountain barrier that rises another three thousand feet, presenting the same forbidding appearance as that protecting Peking.

Now one must put off the luxuries of civilization and adopt the primitive ways of all frontiers. So we must take to our field equipment and begin our real journey of exploration. It is possible that some of us may not return, but if and when we do return we shall have had our try at one of the most interesting exploratory experiments of modern times. The camel caravan with supplies has already been long on the trail. They must be several hundred miles out, so we can afford to use the best devices of modern invention for swift travel to save the time and energy of the scientists who are to unravel the story of the wastes beyond the mountain barrier.

If one goes farther these heights must be scaled. The trail is rough, almost impassable, as one follows the boulder-strewn bed of a stream course and climbs the last three thousand feet to the very top of the range. And then a surprising thing happens. One finds that he has not climbed a real mountain range at all. Instead he finds himself on the edge of a great plateau, which stretches out into rolling landscapes as far as the eye can reach. It was only



THE WESTERN HILLS BEYOND PEKING

THIS MOUNTAIN RANGE FORMS THE FIRST GREAT BARRIER TO TRAVEL TOWARD THE INTERIOR OF ASIA.

the rugged, deeply eroded face of this plateau that looked like a mountain range from the valleys below.

This is the inner border of Mongolia; the edge of one of the great interior basins characterizing Central Asia. This is the gateway to the Desert of Gobi. For nearly a thousand miles these rolling landscapes stretch out to the north, and for more than three thousand miles east and west. This is the land we have traveled so far to see. This is the region where the Central Asiatic Expeditions spend half a year at a time entirely out of touch with the civilization that we know. The people of this strange land maintain the customs of a thousand years ago. It is an easy step here to the much more ancient records preserved in the rocks of the earth itself.

It is not sufficient for our purpose, however, to know that this is the Desert of Gobi. That has been known ever since man first found his way across these barren tracts in prehistoric times. Men have lived here probably about as long as they have lived anywhere. These wastes have seen one people after another develop and prosper under the favor of kindly times, only to be driven out in its periods of severity, marked by reversion to desert climate. So the migrations began that have changed the face of one civilization after another ever since the dawn of man. Therefore it is not at all an unknown region. Travelers and adventurers and merchants have followed these trails ever since man began trading with his neighbor beyond the Great Wall. The nature of the land itself and its people were known, but the things belonging to its scientific story have remained hidden in a record that no untrained man could read.

Before I go into that matter further I must explain what the Desert of Gobi is like and why one goes there to carry on scientific explorations. Why should any one pick out this desolate place?

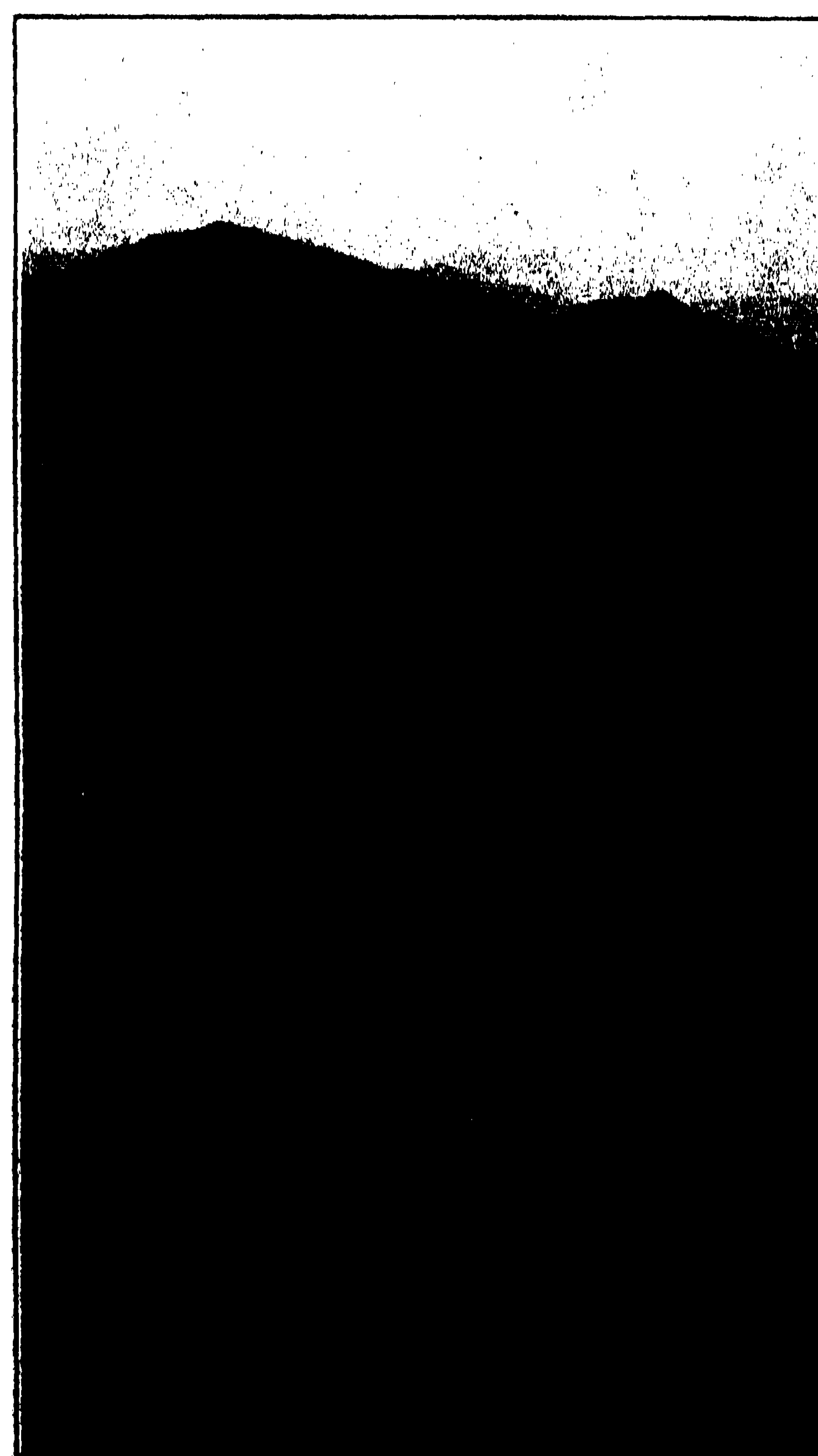
Once upon a time, geological ages ago, this portion of the earth was mountainous, with all the complicated structures that belong to such a region; its mountain ranges stood as high and as rugged as any others of their kind. But they were so long exposed to the destructive attack of the weather and the erosion, the winds and the rains, that the moun-

tains were literally worn away. The rivers of that time carried to the sea one particle after another, loosened by weathering, until the whole mass was worn down. The result was as if one had taken a great hand plane and had shaved off the elevated portions, throwing the handfuls of shavings away into the sea to help build up there the lands that eventually made the rest of the continent that is now Asia.

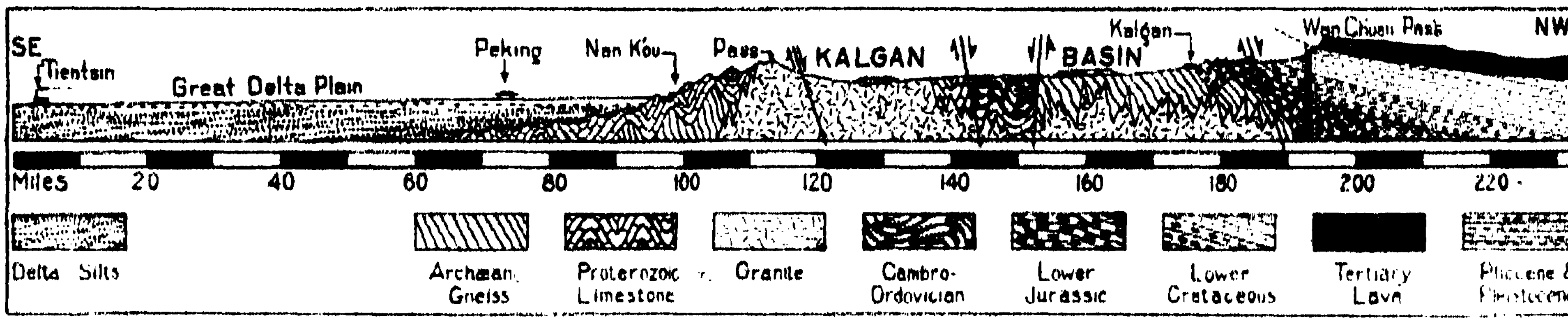
These erosion processes continued, year after year, age after age, until the surface of the land became like a great floor beveling across the roots of the ancient mountains, the tops of which had been carried away. It must have been a low-lying land, not very much above the sea-level of that time. It must have looked like the end of all things, but in reality its most interesting happenings had just begun. With the help of subterranean forces, the character of which is not very well understood, the whole central portion of the continent, hundreds of thousands of square miles in area, was lifted high above its former level. But the outer edges were raised higher than the middle portion, which sagged a little, so that the whole area took on a basin-like form. Then the streams that aforetime flowed out of this region, carrying their load of sediment to the sea, turned inland and deposited their burden upon the bottom of the basin. There, on the old erosion floor, these new sediments have been accumulating, one layer on top of the other, ever since that time. These are the so-called Later Sediments of the Gobi region.

Because the borders of the basin are higher than the interior, half a mile higher, the moisture-laden winds from every direction precipitate rain and snow there and pass to the interior as drying winds. So these borders are comparatively fertile and reasonably prosperous, whereas precipitation fails in the interior, and this portion is desert. The Gobi is only one of a series of similar desert basins stretching across Asia.

The story would be comparatively simple—but exploration nearly hopeless—if it had not been for the renewal of uplifting and deforming movements. From time to time after deposits began to accumulate, portions of the basin were deformed. In certain places it was depressed still more, and in other places the floor was lifted so that smaller basins and intervening bulges were formed. Then the sediments that had already collected were eroded from the uplifted



THE GREAT WALL AT KALGAN
THIS SHARP-POINTED WALL LENDS PROTECTION TO THE CITY OF KALGAN.



—*From the American Museum of Natural History*

DIAGRAMMATIC CROSS-SECTION

FROM THE COAST AT TIENTSIN TO THE BORDERS OF MONGOLIA AT WAN CH'UAN PASS, SHOWING THE FOUR GREAT STEPS IN REACHING THE INTERIOR: THE GREAT PLAIN; THE FIRST MOUNTAIN BARRIER; THE KALGAN BASIN; THE SECOND BARRIER FORMED BY THE EDGE OF THE PLATEAU OF MONGOLIA. THE CHANGES IN UNDERGROUND STRUCTURE ARE ALSO INDICATED. DRAWN BY F. K. MORRIS.

portions and were redeposited in the adjacent deepened basins, forming a second layer of Later Sediments there. Such disturbances as these have continued to the present day, accompanied by corresponding shiftings of erosion and deposition to match the warpings of the basin floor. As a result one may now cross many large areas where the ancient floor is exposed, and pass from these on almost the same level to similar large areas of smooth ground underlain by accumulated sediments. As the result of such history the sediments in many places are thin and represent only a small fragment of the whole story. In other places they are comparatively thick and successfully record long chapters of geologic history.

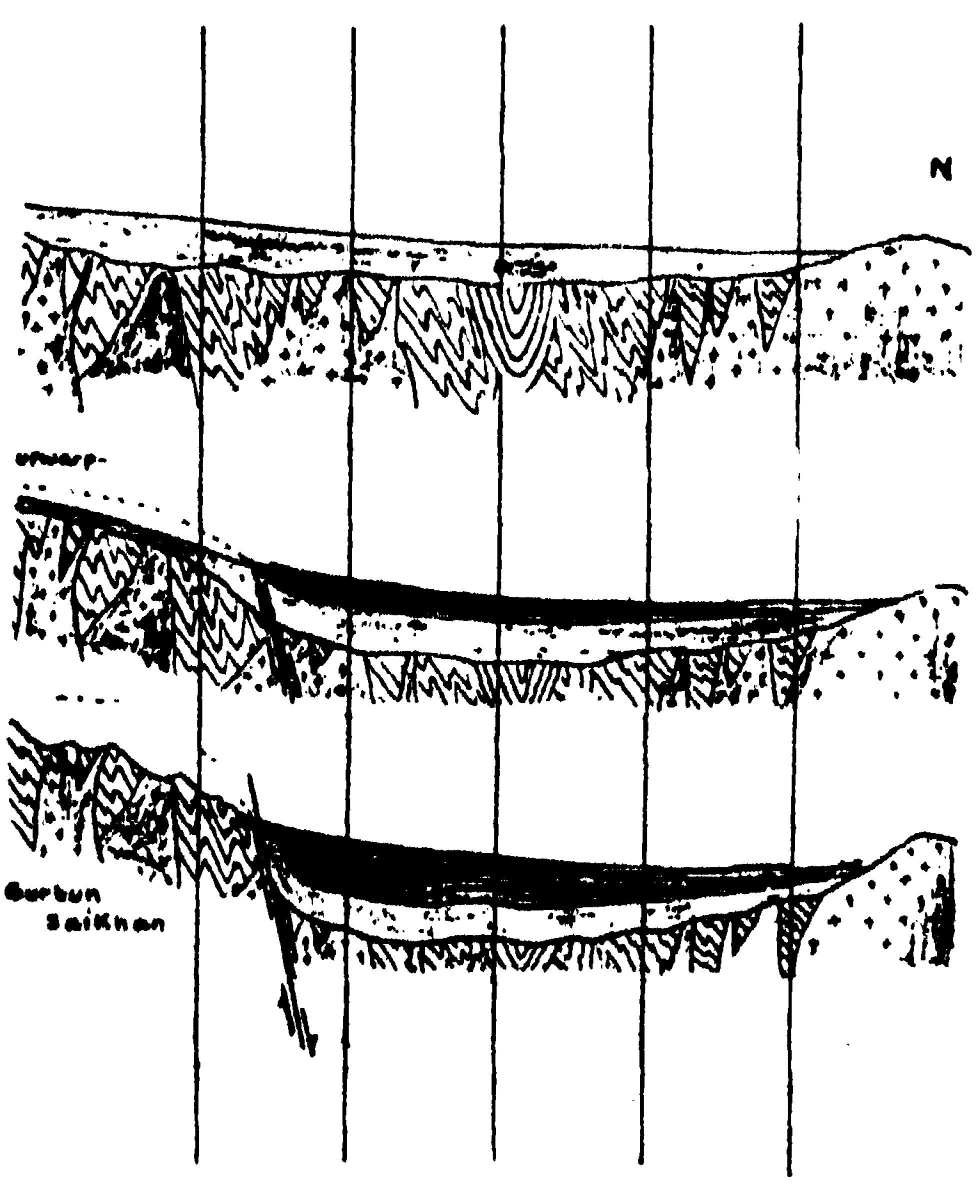
From the very beginning of this continental history, ever since these basin sediments began to form, geologic ages ago, this portion of Asia has remained above sea-level. The animals that roamed over these plains were never driven out by the sea, although they may have been forced at times of great aridity to migrate to more hospitable adjacent lands. Here they lived and here in these sediments their bones are buried with the rest of the débris. The strange creatures that inhabited this interior region for tens of millions of years are represented in the fossil remains. Some of them were drowned in the rivers; some sank to their death in treacherous quicksands; others mired in the borders of muddy lakes and their bones were covered by the silts that were washed in so that now they lie buried as fossils in these sediments, and yet others died in the open and were covered by drifting sands.

If the strata were not exposed there would be small chance of recovering many of these remains, but wherever there has been deep erosion, or wherever the strata have been warped up or faulted so that their edges are exposed, there it is worth while looking. Then if a good place is found where the bones are well preserved and if one knows the value of bones when he sees them, it is possible to discover a new type or secure a whole museum full of material.

It all looks simple enough after the story is unraveled, but it is a hopeless outlook as one for the first time faces the discouragements of a desert waste and the uncertainties of wholly unknown ground. After the key is discovered and the elements of the history are determined, one may traverse a hundred miles with entire confidence that there is no need to search for fossils there, for this is the ancient floor. On another stretch, recognized as underlaid by Later Sediments, one can be equally cer-

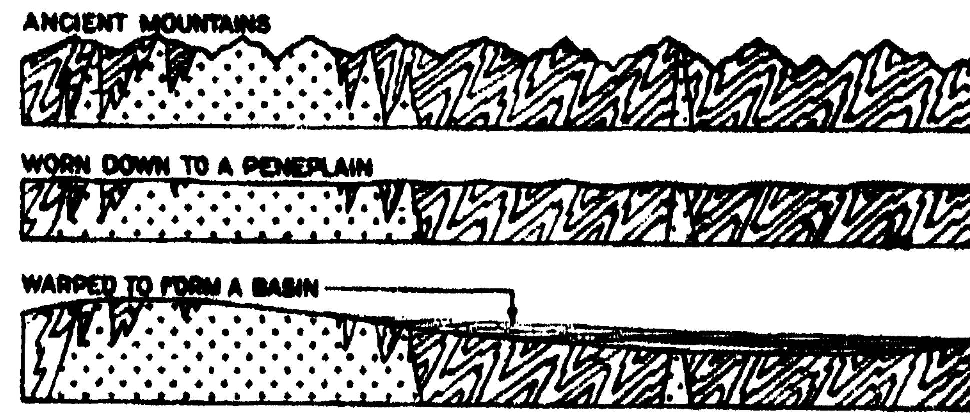
tain that it is promising ground and that one must stop and inspect the strata beneath if a place can be found where erosion has exposed them. Valley-side bluffs, gulches and badlands are all closely scanned. If fragments of bone are found the search is continued, and partially exposed remains are excavated with the greatest care.

Through the work of the Central Asiatic Expeditions it is now known that Central Asia has some of the finest fossil fields in the world. When the work began no one knew that. Yet Central Asia had been known since earliest times. These deserts lie athwart



DEVELOPMENT OF A SEDIMENTARY BASIN

DIAGRAMMATIC SKETCH SHOWING THREE STAGES: (TOP) THE FIRST SEDIMENTS BEING LAID DOWN DIRECTLY UPON THE SMOOTHED FLOOR OF ANCIENT ROCKS; (MIDDLE) THE BASIN DEEPENED BY FAULTING SO THAT THE SEDIMENTS AT THE LEFT WERE CARRIED OFF AND DEPOSITED ON THE DEPRESSED PORTION AS A NEW OVERLYING FORMATION; (BELOW) THE SEDIMENTS ENTIRELY SWEPT FROM THE UPLIFTED AREA AT THE LEFT AND ACCUMULATED AS A THIRD FORMATION ON THE DEPRESSED BLOCK. DRAWN BY F. K. MORRIS.

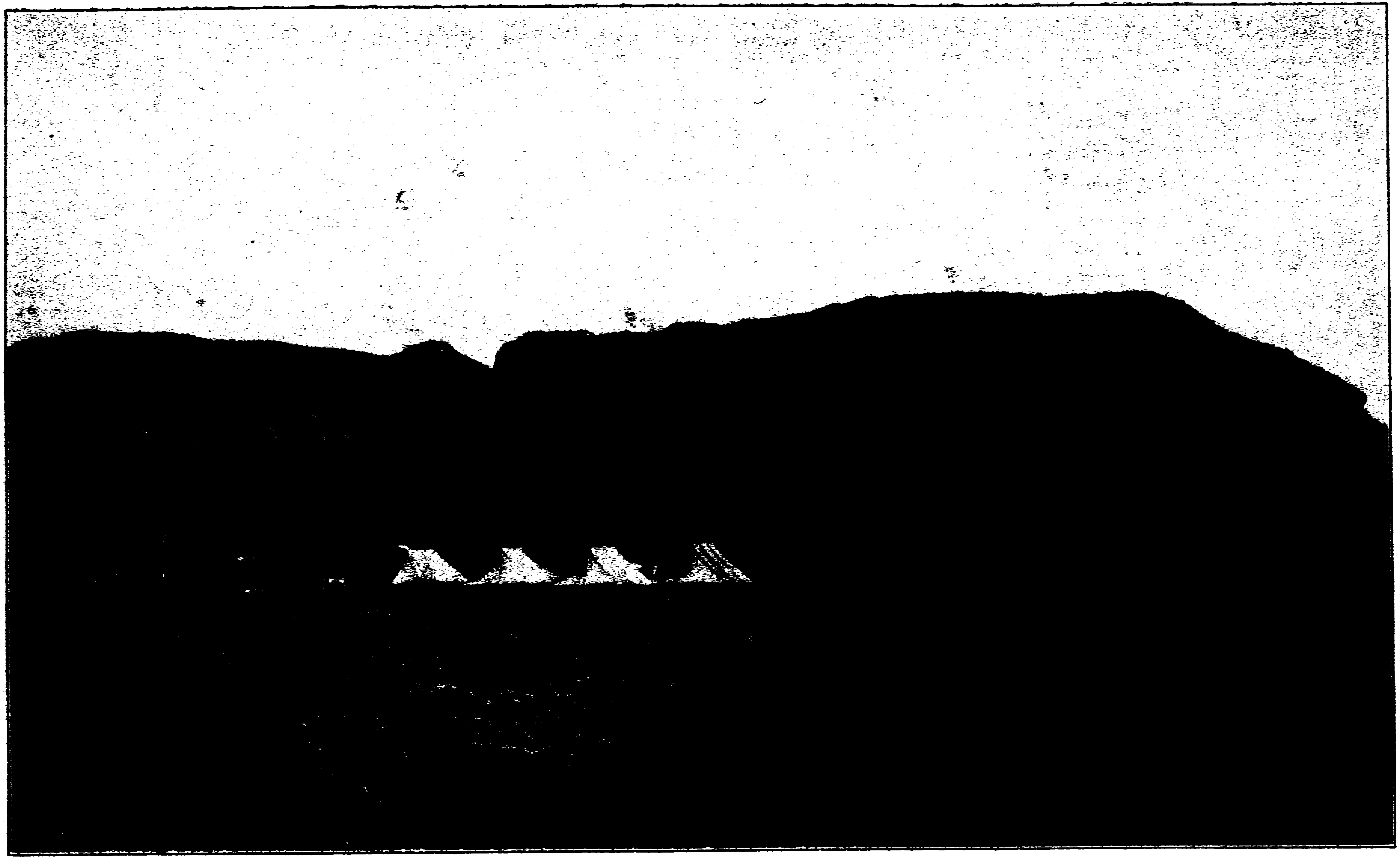


DIAGRAMMATIC SKETCH

SHOWING THREE STAGES IN THE DEVELOPMENT OF A SEDIMENTARY BASIN FROM A MOUNTAINOUS AREA. DRAWN BY F. K. MORRIS.

the trade routes of the ancient world, and they have been traversed ever since commerce began. One people after another has occupied this region from prehistoric times, so it is not a *terra incognita* in that sense. Only its scientific elements were unknown. The traveler of modern times found enough privation and danger in this forbidding country to occupy his whole attention, and he was glad to escape with his life. The drifting sands, the terrific unabating winds, the burning sun and the barrenness and emptiness impressed him, but the records in the earth beneath his feet and the evidence to be found there bearing on the manner in which these desert lands were made and the kinds of animals that lived there in past ages made no appeal. So despite thousands of years of history and tens of thousands of prehistory, the scientific story of the Gobi desert was until recently almost as unknown as it was in the time of Adam.

Within a week of the time the expedition started, on one of the ancient Tartar trails over which caravans have traveled for thousands of years, and within a hundred yards of the well at Iren Dabasu where all these travelers have camped from time immemorial, the first dinosaur bones were found, the first ever found in Central Asia. Of course no one before had been looking for bones; no one had any particular use for the stray bones of animals dead as long



—*From the American Museum of Natural History*

A DESERT CAMP

IN THE BACKGROUND ARE BRIGHT RED CLIFFS, CAPPED WITH BLACK LAVA. THE FLAT-LYING SEDIMENTS BELOW CARRY LAYERS OF HARDER AND SOFTER STRATA, YIELDING DIFFERENTLY TO EROSION AND GIVING STEP-LIKE BENCHES. HERE WIND AND WATER ARE CONSTANTLY AT WORK DESTROYING THE BEDS THAT FORMERLY EXTENDED CONTINUOUSLY ACROSS THIS LOCALITY.

as these. Only a scientist finds such things interesting and worth while. It is not quite clear to the native to this day why any one should do so useless a thing, or anything else for that matter which does not have to be done.

The Asiatic Expeditions, however, were organized to do just such work. Beginning in a very unpretentious manner, they were at first largely concerned with collecting exhibits and study collections for the American Museum of Natural History in New York City. The first two expeditions—those of 1916 and 1919—were planned, organized and executed by Roy Chapman Andrews, acting in all capacities—as originator, leader, transportation and diplomatic director, foreman and the whole scientific staff himself. The scientific venture was modest, and the traverse had to be limited to the trails that men may follow with some assurance of safety.

It had become apparent, however, that Central Asia, with its scientific story almost unknown despite its long human history, presented a real opportunity. This was true partly because its people have cared much for art, philosophy, literature and religion but little for science. And it was true partly also because of the comparatively inaccessible and inhospitable nature of the interior of Asia. Otherwise, foreign travelers—called explorers when they become students of little-known physical conditions in out-of-the-way places—would have studied the region long ago. Those more adventurous individuals who had penetrated portions of this vast interior basin country had found it quite impossible to make systematic investigations extended enough to construct a connected and comprehensive story.

On the more hospitable borders, however, such work had been going on for many years, and significant and valuable contributions had been made. The most outstanding were those of the late Raphael Pumpelly, the veteran American geologic adventurer; of von Richthofen, the pioneer German explorer; of Obruchev, the great Russian geologist, who penetrated far into the desert country of both the Gobi and Dzungaria; of Sven Hedin, the famous Swedish explorer, whose delightful accounts of his travels among strange surroundings, especially in the high plateaus of Tibet, are classic; and of Dr. Bailey Willis, another American geologist, whose researches in China are fundamental studies. These deserve more recognition than any others, although there were many others. Their works were the chief guides for those bent on exploration. One could begin there.

After two years of preliminary work along the borders between the slightly known and the almost wholly unknown regions, Mr. Andrews began planning for a third expedition. It had become clear both to him and to his chief sponsor, Prof. Henry Fairfield Osborn, president of the American Museum, that a more elaborate expedition was fully warranted. Professor Osborn had long held that Central Asia was likely to produce valuable evidence in the story of the evolution of the vertebrates. Thus it happened that the Third Asiatic Expedition, that of 1922, became an exploratory investigation so constituted and operated as to make feasible the penetration of otherwise inaccessible territory, covering many times more ground than had ever before been possible in a single season.

The study of the geologic and paleontologic history of Central Asia was begun that season, and has been continued ever since, with additional field work in the summers of 1923, 1925 and 1928. In 1925 archeological and botanical studies were added. Each time large collections of rocks, fossils, animals and plants were made. Each time, also, more or less elaborate investigations were suc-

ROY CHAPMAN ANDREWS, LEADER (RIGHT) AND F. A. LARSEN, INTERPRETER
EXHIBITING ONE OF THE LARGEST BIRDS OF THE GOBI REGION.

cessfully carried on in the field, and material was gathered for the continuation of such studies in the laboratory.

As long as running accounts of progress or special notices of particular finds were the chief matters published, the individual character of successive expeditions could be emphasized. In this way the Third Asiatic Expedition came to be widely known. But as soon as more formal publications were undertaken, especially where summaries of results were included, it was clear that distinctions between the different expeditions could not be maintained, and that a more general designation should be adopted. For this reason, the more comprehensive name, the Central Asiatic Expeditions, has been applied to the whole series, both for the field work and for publication.

Perhaps a bird's-eye view of operations should be given to furnish the picture a matter-of-fact background. The expeditions have covered approximately 25,000 miles of traverse across little-known or wholly unknown territory. Approximately 1,700 miles of route traverse have been mapped with considerable reconnaissance accuracy by topographic methods, and more than 5,000 miles of traverse have been covered with geological structure sections, while more than 2,000 square miles, distributed in twelve separate areas, have been mapped geologically in considerable detail. More than 260 cases of fossils have been recovered, in addition to botanical, zoological and archeological collections. These collections are of quite indeterminable value. Much of the material is absolutely new to science, so that there is no basis of estimate or comparison.

These are the more obvious statistical facts, but back of them is a story that reaches out into many fields of science. One of the strongest points of the expedition is the fact that the field work was done by the whole group together.

GEOGRAPHY

There were maps of Mongolia before, but they were all bad. The major

routes of caravan travel cross the region about where these maps indicate, and most of their mountain ranges exist, but they are never at the right spot. Sometimes they do not even show the right course, and none of the detail is dependable. On this account the maps and other geographic observations of the expedition constitute valuable data, usable for correction purposes.

A large number of route maps and detailed locality maps were produced. Those of the season of 1925 were made by Major L. B. Roberts and those of 1928 by Capt. W. P. T. Hill. About one thousand miles were covered in this manner, beginning at Kalgan and reaching beyond Kholobolchi Nor, not far from Uliassutai. Locations were derived from solar observations; distances were kept by automobile speedometer; orientation was obtained independently of possible magnetic variation by means of solar chart; differences in elevation were secured by vertical angles, and, in general, plane table methods were used.

Detailed topographic maps of five type areas were made with an accuracy comparing favorably with the topographic sheets of the U. S. Geological Survey. These furnish excellent base maps for other branches of the work, particularly for geology and paleontology.

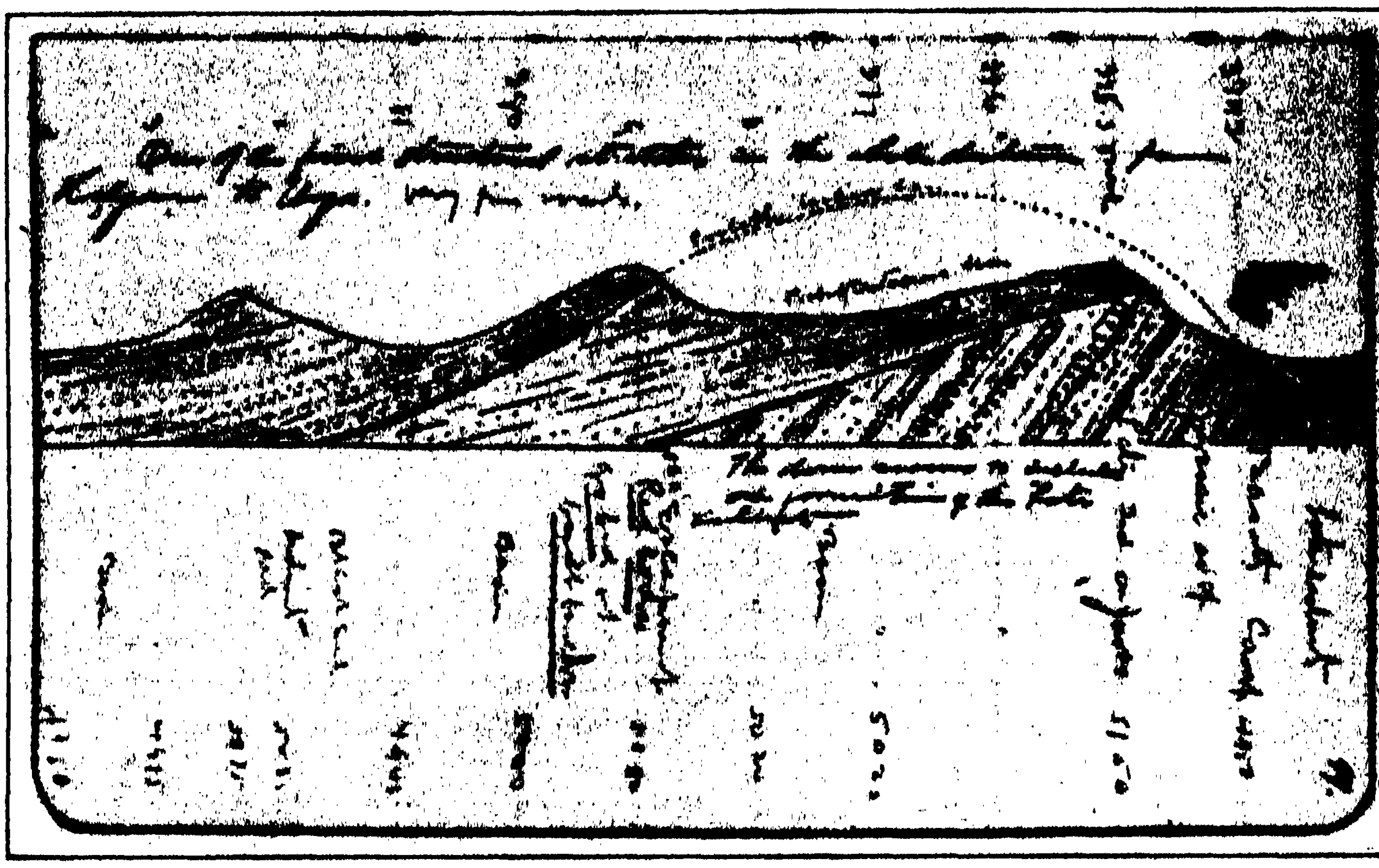
Geology

The Central Asiatic Expeditions have made two notable contributions to geology. Of these the more tangible is represented by the classification of

—From the American Museum of Natural History

FOSSIL BONES

A GROUP OF BONES PARTLY UNCOVERED AND STILL IMBEDDED IN THE ROCK WHERE THEY WERE BURIED AGES AGO, SHOWING HOW PLAINLY MARKED AND HOW WELL PRESERVED MANY OF THESE FOSSILS ARE.



A TYPICAL PAGE IN THE GEOLOGIST'S NOTEBOOK

A CONTINUOUS SERIES OF CROSS-SECTIONS, SUCH AS THIS, RECORD THE GEOLOGIC STRUCTURE OF THE COUNTRY ALONG THE ENTIRE LINE OF TRAVERSE, IN TEN-MILE STRETCHES. THE NUMBERS ABOVE THE SKETCH SHOW DISTANCES IN MILES; THOSE BELOW RECORD ELEVATIONS ABOVE SEA-LEVEL. THE NOTES ARE CATCH-PHRASE DESCRIPTIONS. IN THIS MANNER THE GEOLOGY OF THE WHOLE ROUTE WAS WORKED OUT AND RECORDED.

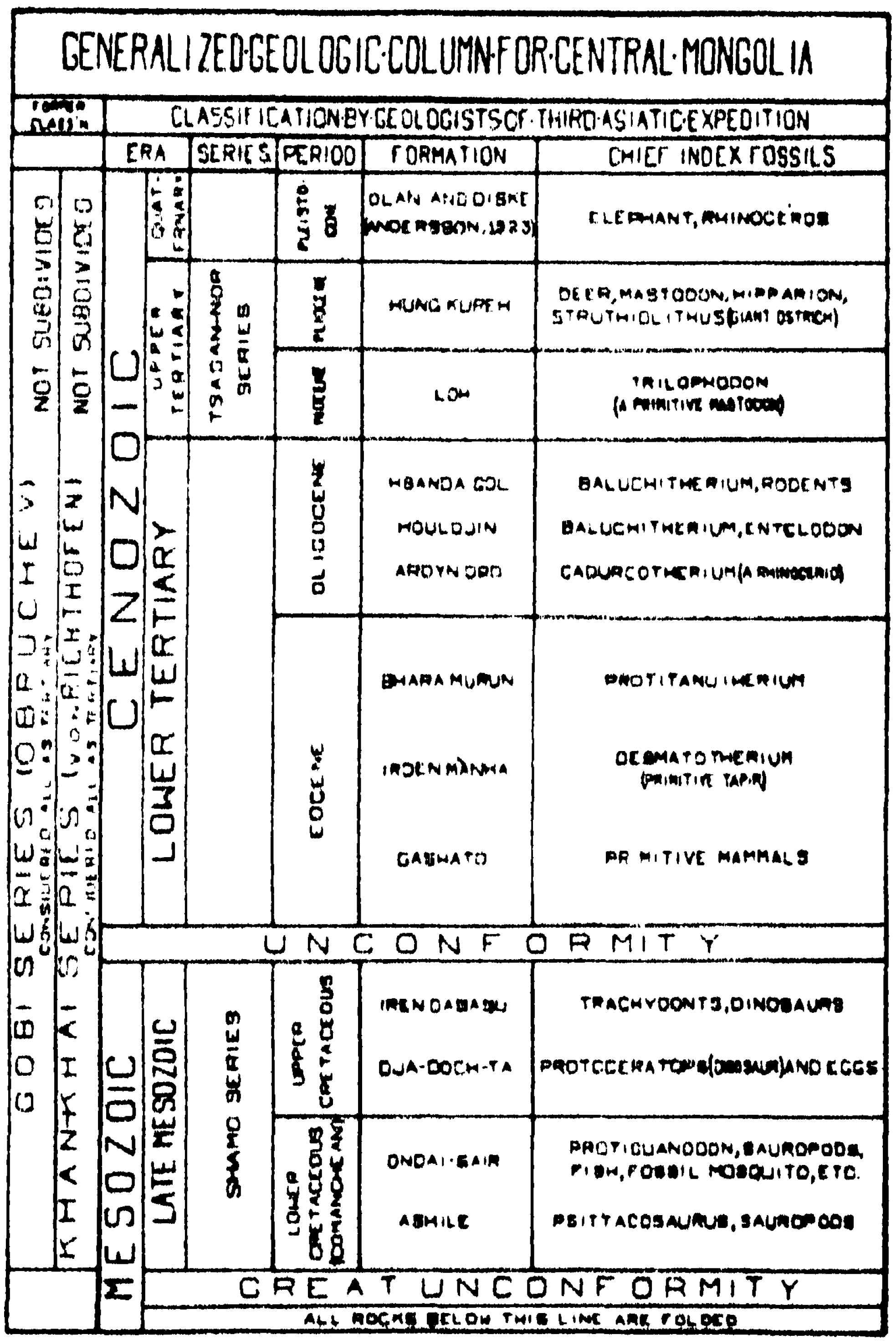
geologic formations and the mapping of rock units and structures for several thousand miles of new country. The less obvious but more valuable and difficult is the interpretation of these formations and related structures in terms of a relatively comprehensive geologic history of Central Asia, the very last chapter of which has to do with prehistoric man.

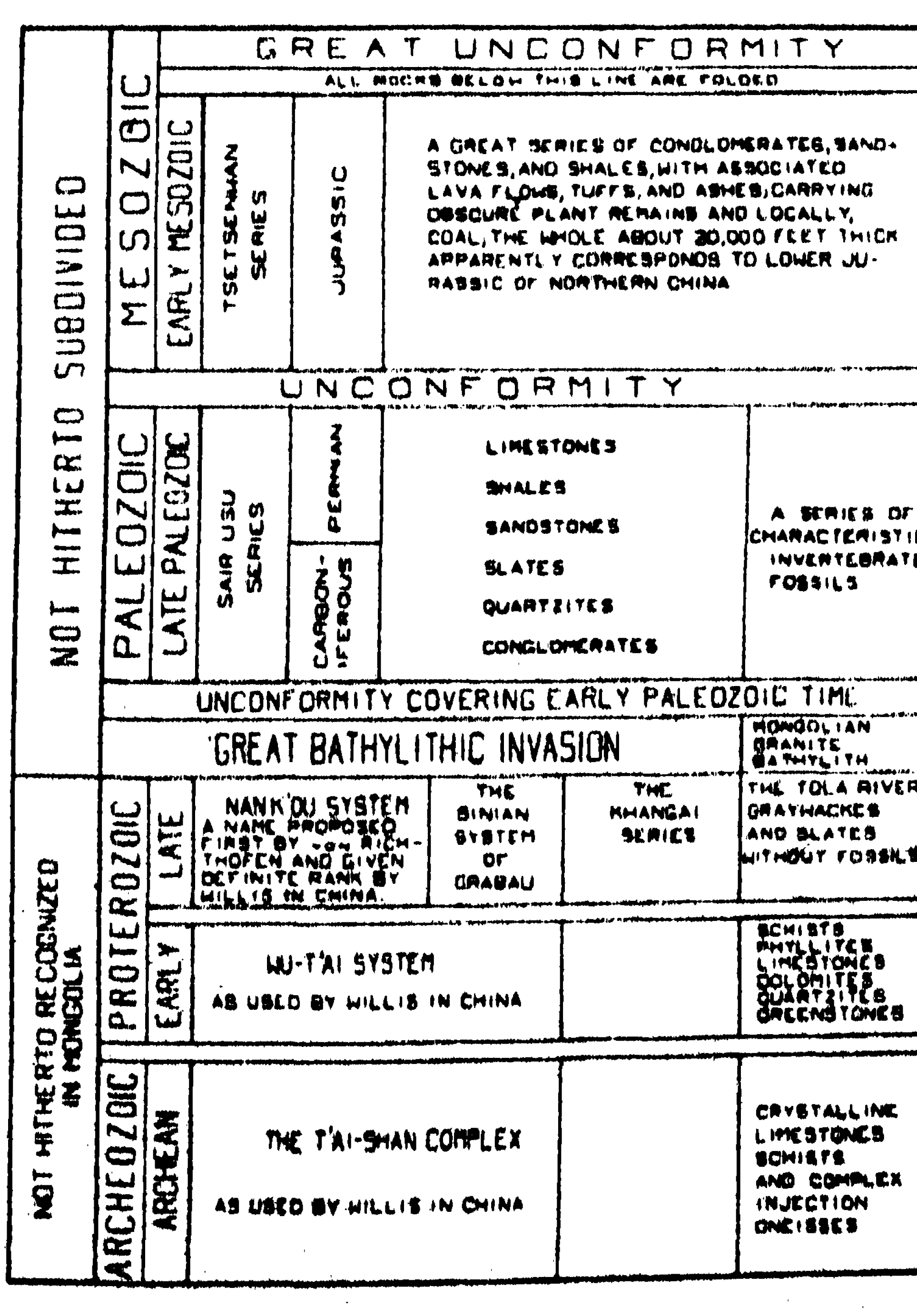
The series of geologic sections, showing the underground structure, covers more than five thousand miles of traverse, fully identified with the physical features of the country. These traverses, therefore, have become essentially geologic base lines, from any point of which new traverses may be begun. They now make a continuous section connecting Siberia on one side with the borders of China on the other, and the studies based on them have given the best understanding yet reached of the major elements of geologic structure of Central Asia.

The geologic column is now fairly well known. For the first time a systematic statement of the ages represented in the rocks of Central Asia has been compiled. The character, thickness, origin and relative age of each has been determined, and twenty-five new geologic formations have been described. The gaps in the record have been noted, and comparison has been made with the standard columns of Europe and America. Additional possibilities and critical localities have been pointed out where further work would be certain to yield results.

Geologic maps of twelve areas have been made showing the areal, structural and topographic features of type localities. A total area of more than two thousand square miles is covered in this manner.

The geologic work of the Central Asiatic Expeditions differs from much exploratory reconnaissance in that the objective kept always in view was the





interpretation of the accumulating mass of data in terms of processes and origin.

Zoology

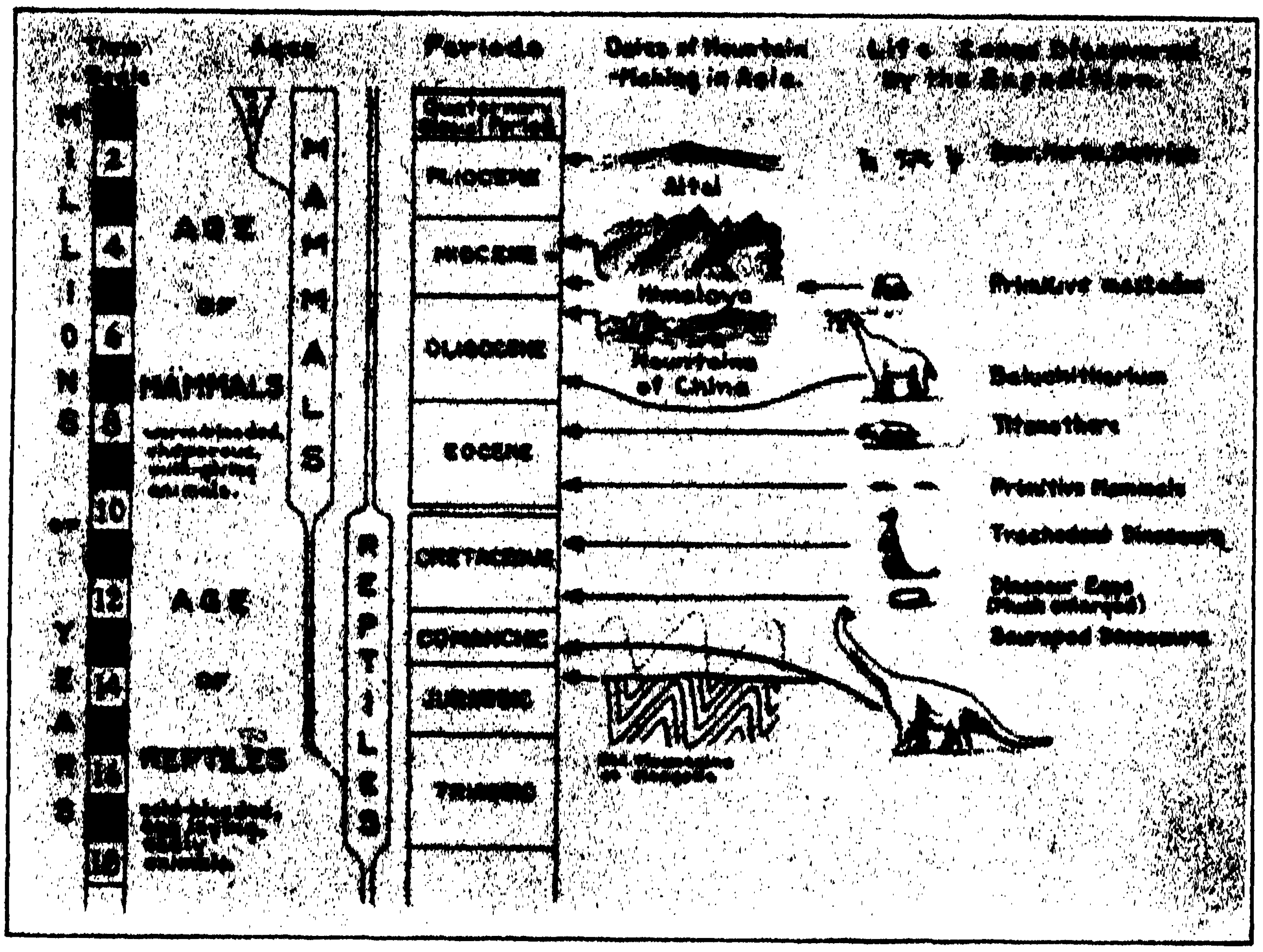
Mr. Andrews with the help of assistants made large collections of living faunas in Mongolia, and Mr. Clifford Pope conducted parallel studies in China.

Some 6,765 specimens of mammals, outside of those collected in 1928, have been deposited at the museum. Dr. G. M. Allen, who is identifying these specimens, finds the portion already worked over rich in forms new to science, no less than fifty new species and sub-species and one new genus having been discovered.

Botany

Dr. Ralph W. Chaney was in charge of botany and paleobotany on the expedition of 1925. He found that fossil plants are scarce and poorly preserved. Living species, however, are numerous and deserve additional attention. Numerous fragments of petrified wood, none of them of great size, have been collected, but no complete trunks of trees were discovered. Some of the specimens are twisted and may be interpreted as representing the growth of stems under an unfavorable environment.

The absence of leaf impressions in the rocks of Cretaceous and early Tertiary age in Mongolia is significant in view of the abundance of such remains in beds of these ages not only to the south in Asia but in western North America, as well as in the Arctic and in much of Europe. If there had been abundant forests in Mongolia at that time, there would certainly have been a better record of them left in the contemporary sediments. The negative evidence, therefore, taken in conjunction with the evidence of such plant fossils as have been found, leads to the conclusion that



—*From the American Museum of Natural History*

DIAGRAMMATIC CHART

INDICATING THE GEOLOGIC PERIODS AND CORRESPONDING FOSSIL CONTENT REPRESENTED IN THE LATER SEDIMENTS OF THE GOBI REGION. DRAWING BY F. K. MORRIS.

the climate in Mongolia was cool and semi-arid, perhaps not greatly unlike that of to-day.

Of modern plants, 624 specimens were collected, including approximately 500 species. The flora of the canyons and high meadows of the Altai Mountains is the richest noted anywhere in Mongolia. Trees are exceedingly scarce, but in the canyons numerous well-established cottonwoods of a new species were found, besides willows and birches. On the higher mountain sides the only conifer, a juniper known as Artsa, grows in abundance. The only trees seen in Mongolia outside of the mountain canyons were scattering elms (*Ulmus pumila*), along watercourses or former streams.

PALEONTOLOGY

Paleontologic investigations were in charge of Walter Granger, who has been on each of the Central Asiatic Expeditions, beginning with 1922. President Osborn, on whose faith the venture was launched, visited the Iren Dabasu district, the place where the first finds were made, and Dr. W. D. Matthew and Dr. W. K. Gregory have done a great deal of work on the collections returned to the museum.

A whole new world has been opened up to the paleontologist by the discovery of a long succession of continental deposits bearing fossil vertebrates, especially mammals and reptiles, and, in addition, a well-determined sequence of formations, each bearing a mammalian fauna that contains some highly specialized local types and some elements of affinity to faunas of corresponding age in Europe or North America.

Much evidence is being accumulated that will have bearing on the hypothesis that Central Asia has been the principal center of origin and dispersal of mammals and the probable source of new types that from time to time have ap-

peared suddenly in the fossil record in Europe and North America. It appears probable that we have the earliest known ancestral ruminants, a more nearly direct line of ancestry of the rhinoceroses than Europe or America has furnished, and new light on the ancestry of various rodents.

The discovery of a new paleozoological region has naturally resulted in a great addition to the known fossil vertebrate faunas. All the species are new to science, the great majority of the genera are new, and several of them represent new or little-known groups of wider scope.

Owing to the extensive collections made and the expert methods of collecting, a large proportion of these new or little-known types are represented by numerous and unusually complete specimens, by skulls and skeletons rather than by the fragmentary scraps that usually are the first fruits of exploration in any new region. A series of over seventy skulls, with a dozen more or less complete skeletons of *Protoceratops,* in addition to the nests and eggs of this reptile, make its character, osteology, ontogeny and habits better known than those of any other dinosaur. Two other dinosaurs are represented by complete skeletons, small in size and primitive in character, throwing much light upon the

—From the American Museum of Natural History

EVIDENCES OF PREHISTORIC MAN

THESE ARTIFACTS REPRESENT THE PRINCIPAL FORMS SECURED IN THE SHABARAKH VALLEY, AND WERE FOUND IMBEDDED IN THE SAND ROCK IN SUCH A MANNER AS TO SHOW DIFFERENT CULTURE LEVELS. INTERPRETATION CAN BE MADE, THEREFORE, SO THAT THE ARCHEOLOGICAL STORY CAN BE CONNECTED WITH THE GEOLOGICAL STORY OF ORIGIN, CLIMATIC CONDITIONS AND TIME.

—From the American Museum of Natural History

PROTOCERATOPS, A FOSSIL DINOSAUR

SHOWING THE SKULL OF THIS RARE REPTILE, FOUND IN THE FINE RED SANDSTONE AT DJADOKHTA. THIS IS THE ANIMAL THAT LAID THE EGGS FOUND BY THE EXPEDITION.

origin and affinities of the iguanodont group.

Half a dozen mammal skulls found at Djadokhta are the only Cretaceous mammal skulls known. The Paleocene fauna, though fragmentary, is yet better material than any fauna of similar age anywhere except that of the Puerco-Torrejon of New Mexico. The mammal faunas of the Eocene period are not only large and varied but contain many skulls and a few complete skeletons besides hundreds of jaws and other fragmentary specimens. The material compares fairly well with the average material upon which our knowledge of American or European faunas of the same period is based, although that is based on the results of fifty or a hundred years of collecting and research.

A most important feature of the Mongolian collecting is that it was combined with thorough and detailed geologic field work, and in consequence the stratigraphic relations and succession of the faunas were well and accurately determined, and evidence bearing on the nature and origin of the sediments in which they were buried and the climate of the time is also available.

Thus within the space of a few years the discoveries of the Central Asiatic Expeditions have converted this region from a *terra incognita* to a country whose paleontologic record is fairly well known. Outside of western Europe,

central North America and Argentina the fossil record of land vertebrates is very incomplete. We know more about it to-day in Mongolia than in Egypt or India, and far more than in any other part of the world. The preliminary studies that thus far have been made of the Mongolian faunas have brought out only a small part of the results that will follow more thorough investigation, but they are sufficient to indicate this as the most important single piece of exploration that has ever been accomplished in vertebrate paleontology.

Archeology

Cultures of both historic and prehistoric relations were found. The historic remains include evidences of former Chinese colonization in the southern border country, represented by successive great walls, millstones, bronze objects, coins, etc.; camp sites and caves formerly occupied by the Mongols; and graves marked by upright slabs of stone, sometimes roughly shaped into human effigies, typical of the northwestern border of the Gobi and regarded as the burials of Turkic princes of the seventh and eighth centuries of our era.

The prehistoric remains include burial places of various types, pictorial rock inscriptions, quarry and workshop sites and habitation sites. The burial places are of various types, such as graves of round, oval and rectangular outlines, fenced by small stone slabs in standing position; graves of roundish outline, covered by single layers of stone slabs or boulders; grave vaults of stone.

—*From the American Museum of Natural History*

THE FAMOUS DINOSAUR EGGS

This shows a portion of a dinosaur nest with several of the eggs already exposed by erosion. The sandstone formation was originally a loose fine sand drifted by the wind, which by hardening has preserved these delicate objects. Bits of shell may be seen protruding from the rock in the background.

PILGRIM LAMAS

MET ON THE SACRED WAY BETWEEN THE TWO TEMPLES IN GOLOBAI IN OLA. THE TABLETS BEAR THE FAMOUS BUDDHIST PRAYER AND OTHER MYSTIC INSCRIPTIONS.

covered by large conical mounds (kurgans) of boulders, often inclosed by circular or rectangular walls also of boulders and of wider dimensions. A number of these burial places were opened, and a few of them yielded both skeletal and cultural remains, dating in one instance as late as the Iron Age.

The pictorial rock inscriptions represent domesticated horse and camel, and several wild animal species, some of which are locally extinct. These petroglyphs, of the type elsewhere in the world identified with the Bronze and Neolithic Ages, are intimately associated with certain of the aforementioned

ONE OF THE TEMPLES AT THE LAMASARY, TUKHUM IN SUMU

THE DECORATIVE DESIGN IS IN DEEP BROWNS AND BRICK RED. UNDER THE CENTRAL PORTICO THE WALLS ARE ORNAMENTED WITH GORGEOUSLY PAINTED MYSTIC SYMBOLS.

burial structures, and like them give evidence of considerable age.

Quarry and workshop sites were found, especially in the steppe region between Ulan Nor and the Artsa Bogdo mountain range where, for a stretch of nearly one hundred miles, red jasper and other varieties of rock suitable for flaking are exposed on the surface. The waste products of the flint worker lie here in vast quantities and the varying degrees of weather coating exhibited by the material indicate that the date of man's first appearance in the locality is of respectable antiquity. Moreover, some of the finished implements found on these sites correspond in type with certain of the Mousterian and Aurignacian tools of western Europe; they would appear to be of Middle Paleolithic age, variously estimated at from 40,000 to 200,000 years distant.

The habitation sites were marked by fireplaces and the presence around them of artifacts of stone, bone, shell, pottery, etc. These sites, of which traces were found in seven widely distributed localities, are characteristically confined to geologically ancient depressions in the Gobi topography, which have later been more or less filled up by partially solidified sand dunes, called the Shabarakh formation. Embedded in this formation occur the habitation floors in question, and at Shabarakh Usu, the type locality, these floors separate into two fairly distinct and superposed cultural strata. Thus, the bottommost level is characterized by chipped flints resembling those of the extreme Late Paleolithic of Western Europe, while the upper level shows nearly all the industrial traits typical of the full Neolithic.

The special significance of the human artifacts found in Mongolia lies in the fact that it is possible to interpret not the culture alone but also the physical environment of early man in the Gobi region. This is done through the careful correlation of geological processes and succession of events with the corresponding archeological observations.

GRANITE COUNTRY

DRIVING ACROSS COUNTRY ON THE GRANITE OF THE ANCIENT ROCK FLOOR, SMOOTHED DOWN BY EROSION

Now I have given a brief appraisal of the major lines of investigation and accomplishment of the expeditions. Some of it has to be matter of fact. It is part of a catalogue of the discoveries of a group of men who gave their attention day after day in a matter-of-fact manner to scientific investigation in the

—*From the American Museum of Natural History*

SUNSET AT TSAGAN NOR

CAMEL TRAIN CROSSING THE BELT OF SAND DUNES LYING BETWEEN THE LAKE, TSAGAN NOR, AND BAGA BOGDO OF THE ALTAI MOUNTAINS.

Desert of Gobi. This was their daily work and this other is their product and reward.

Many mere incidents of the journey, however, have left quite as lasting impressions on our minds. Never shall we be likely to forget the wild life, the great herds of antelope and of wild ass, the fierce wild dogs, and the sand grouse flying from nowhere to nowhere by the thousands every day. Neither shall we forget the simple poverty of the people, or the attractiveness of a fine lamasary with its group of temples and shrines and its hundreds of small huts to accommodate the resident lama priests. Some of these places are as impressive in their own setting and as great a contrast to the living quarters of the common people as are our own towering skyscrapers in the setting of New York. Nor is one likely to forget the old high priest who is probably still sitting where we found him that day chanting his Buddhist prayers with an earnestness that leaves no doubt whatever of the seriousness of religion in his life. One can still hear the call of the great trumpet and the rumble of hundreds of male voices joining in the daily chant in the service of Buddha.

One day after traversing a thousand miles of desert, we came to the borders of the Gobi, where the plain merges into the hill country of the Arctic Divide. Then after turning into a side valley we saw a mountain that at once claimed special attention. Its like we had not seen before in all Mongolia. Its simple, dignified outline, its long sharp crest, below which a black talus fringe fell like a drapery far down its furrowed sides, marked this mountain with a distinction.

We knew from our own experience, which by this time had given a working knowledge of the geology of the region, that this mountain must have a story of its own. So we were not greatly surprised at the reply of the high priest, a prince of the ruling house, a descendant of the Khans of earlier days, who dwelt there. "Yes," he said, "you may make a study of the spring and the mountain, but you must not kill anything, for this is holy ground."

Probably ever since people have lived in this region the mountain has been regarded with special veneration, not so much because of its distinguished appearance as because of the potential magic of the spot. Here hot waters issue from the ground. These are the healing waters of Sain Noin. If one bathes in them, he is cured of his ills. It must be that they have magical properties, and it may be that they bear to the surface at this singular place something of the supernatural that belongs to that other world beneath. It is a holy spot, and this impressive mountain, overlooking it as if guarding the place, is the Sacred Mountain of Sain Noin.

Here I suppose tribes have gathered ever since the beginning, at first with a feeling of awe, ultimately in reverence and worship, the ceremonies changing with the shifting of peoples, the advent of new religions, the lapse of time, and the varying imagination and spiritual insight of the priest who led them.

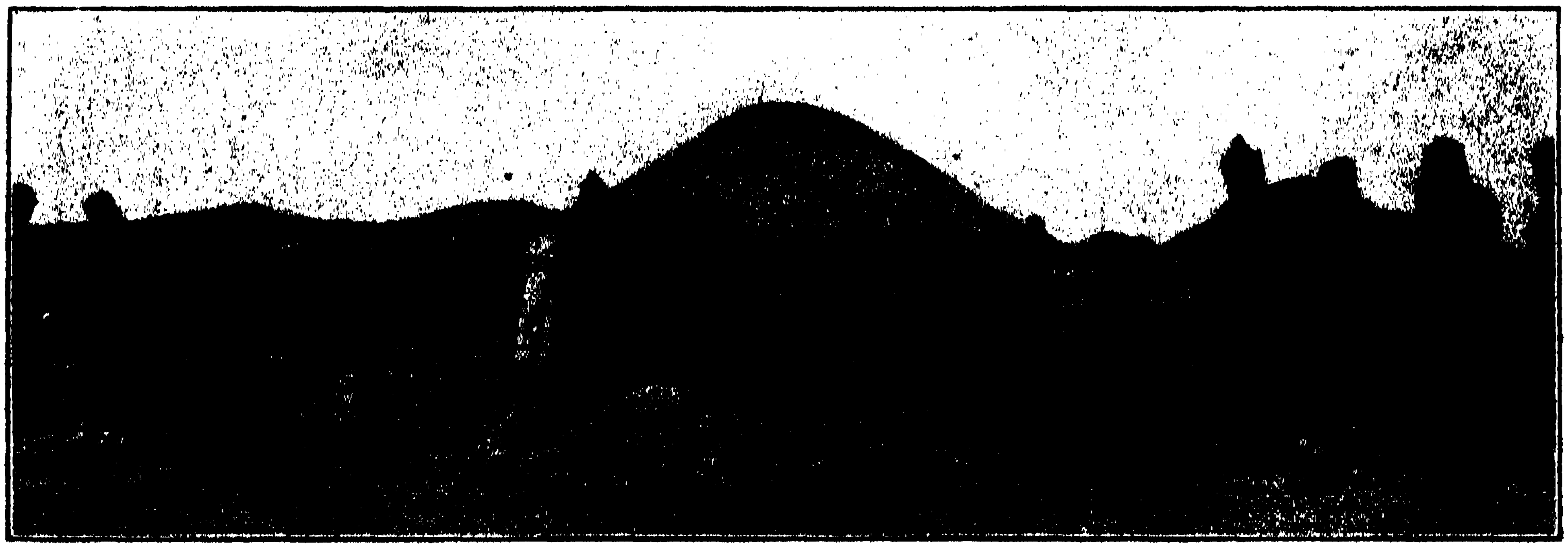
When we were all through, the map made, the sample of water secured, the reasons for the whole combination of unusual features worked out, and the time had come to make adieus to our priestly host, we thanked him for his assistance, and assured him of our great interest in the local phenomena.

Then he said, "Have you had a bath?" I had not, and when he indicated that he wanted me to bathe in these healing waters I realized that it must be a ceremony. So I agreed at once and he led me to the spot where several springs issued, and said, "This is your bath and this other is mine."

There under a blue Mongol tent I found the granite rock hollowed out, with stones lying around the edge and waters as hot as one could bear issuing from the crevices in the bottom of the bowl.

Of course one ought to reciprocate, so we said to him, "You have given us what we have asked of you, now we are about to turn back. Within an hour we shall break camp and be on our way. By and by we hope to reach our own country on the opposite side of the earth. Is there anything you would like us to send you?" Then I got one of the shocks of my life, for he replied, "Yes, I would like you to send me an analysis of the water."

For a moment it took my breath away, but upon reflection it was not so surprising. Don't you see that we had discovered in this high priest of Buddha the elements of a scientific mind? If he had been born in America he would have been a scientist, and on the other hand if I had been born in Mongolia I suppose I would have become a Buddhist priest. Thus far apart are the opportunities of the two countries—as far almost in that respect as they are in physical position on the face of the earth.



THE GUARDIAN OF THE SACRED MOUNTAIN

THE PRINCE OF SAIN NOIN, A HIGH PRIEST OF BUDDHA, STANDING BEFORE THE DOOR OF THE ROYAL YURT, WITH HIS ATTENDANTS. IT IS A BREACH OF ETIQUETTE NOT TO ENTER BY THE GATEWAY IN THE STONE WALL.

THE VIBRATO IN CELEBRATED VOICES

By Dr. MILTON METFESSEL
THE STATE UNIVERSITY OF IOWA

I

RUBINI, the Italian tenor, is generally credited with introducing the vibrato into artistic singing in the early part of the last century. From then until now there has been a controversy among voice teachers as to the merits of a pulsating voice, with all the shades from approval to otherwise. There are those who denounce any vocal quivering whatsoever as inartistic, while others compromise in maintaining that pulsings are not jarring in passages where a trembling voice would naturally express strong emotion. A third group distinguish between the vibrato and tremolo, ascribing beauty to the former and ugliness to the latter.

Five years ago, when an experimental study of the vibrato was begun, it was evident that an attempt to throw any light on these differences would necessitate a new attack. Accordingly it was decided to leave out any possibility of personal equations, and to resort solely to mechanical devices.

Since then cameras for photographing sound waves coming from the vocal cords have been perfected to a high degree of accuracy. A voice photograph gives a more accurate and detailed description than is possible with the best unaided ear. The vocal cord vibrations are magnified a thousand times on moving-picture film in order to produce a picture large enough to study each individual wave, whereas the ear does not lend itself to such minute analysis, grasping only gross effects.

By measuring each wave-length on the photograph, any periodic variations in the voice however subtle, will be objectively ferreted out and notated. If there is a vibrato in a voice, the photograph will not only reveal it, but record it for measurement exactly as it is without partiality.

The voices of Caruso, Galli-Curci, Chaliapin, McCormack, Homer, and a score of other concert and operatic artists were photographed from phonograph records. What of the vibrato? Suffice it here to say that it was photographically detected in ninety-five per cent. of the tones. Any one playing a record of any recognized artist can verify the almost continual presence of this pulsation. If it is not immediately evident, the record may be slowed down until it becomes definitely perceptible.

Because it is so universal in artistic singing, it is fairly safe to hold that the vibrato has been tried and found beautiful. The occupants of the seats at the Metropolitan sit in collective judgment on whether a voice is beautiful or not. No matter how enthusiastic the "discoverer," his protégé must have a public. That public is ever ready to pick out the least flaw. Out of the many factors making for beauty, the absence of any one of them may destroy the effect of all the rest. It can not be just happenstance that vibratos are not only admitted, but required, in opera.

II

Measures of the sound waves of nearly three thousand vibrato cycles of recognized artists justify the statement that a vibrato to be desirable must have certain properties in just the right balance. Two of the most important properties are rate of pulsing, and extent, or the amount it rises and falls on the scale.

These properties vary within certain narrow limits without upsetting the equilibrium. Caruso sang one tone with a vibrato quivering eight times per second with an extent of a quarter-step, and the next tone surprisingly jumped to three-quarters of a step and six pulses per second. Such extremes actually are rare. Most rates cluster around the average of seven. His extent has a range from one tenth to a little over a whole-step, with the majority of extents occurring in the neighborhood of a half-step.

It is an interesting speculation that if Caruso had had a vibrato with an average of only six pulses per second—and this is the case of many music students—he would never have been an operatic star. None of the operatic artists studied averages as low as six. They all have about the same range of rate and extent as Caruso. This close correspondence of vibrato cycles of those who reach the heights is significant, representing a condition that seemingly must be met by the vocally ambitious.

From the sound wave analysis it would appear that anything so disjointed as a seven per second fluctuation of a half-step would be anything but beautiful—a violent auditory confusion. How can an artist whose voice shakes to such an extent sing in tune, to say nothing of following any standardized scale?

The answer—and here experimentation with ears is necessary—is that these changes are not heard *per se* in ordinary musical perception. A tone is generally grasped as a whole in consciousness, a phenomenon technically known as a *gestalt*. The hundreds of sound waves crowding in upon the ear of one enjoying music are given their own way, and they pile up on one another in the hearing process. A vibrato at a rate of seven times per second and an extent of a half-step is not a rise and fall of pitch in such a situation.

The variations fuse and produce an effect that is beautiful and unique. The tonal mass has one salient pitch at its focus, surrounded by a halo of tone-coloring peculiar to fast fluctuations. That salient pitch is generally close to mid-way between the extremes on the scale reached by the actual sound waves. For instance, one of Caruso's tones, measured on the sound waves, has a vibrato with a crest at C sharp and a trough at B, but on testing for the pitch heard, it is found to be approximately C with most observers.

It may be laid down that as long as fluctuations in a tone fuse into a steady predominant pitch, those fluctuations will be acceptable. Behind this statement are experiments in the laboratory in which conditions are so controlled that the balance of properties in the vibrato is broken down by one means or another. For instance, if the rate is too slow the fusion is lost, for there appears a continual shuttling of two notes. Observers complain that it becomes as disconcerting as hearing the same section of a melody over and over.

III

Having found that the vibrato is an integral part of artistic singing, and that to be beautiful it must have properties which are present in correct balance, resulting in a unitary pitch set in a variety of tone-colorings, it remained to see if there were any possible explanations for the radical differences of opinion.

An English musician-writer, who found part of his joy in life in railing against vocal pulsations, had his voice graphically recorded in Professor Scripture's laboratory in London. The professor kindly showed these records to the writer, and even a die-hard denouncer would have to admit the presence of the vibrato. The English musician is typical of a large group who talk about the

vibrato, but who have never analyzed their own voices for it. They are content to apply that title only to those pulsations which beat upon them violently, excluding all those of lesser insistence, similar in every other respect.

A hunter of cold facts is not surprised to find that a vibrato is an integral part of artistic singing, until he reads the musical literature. An American musician recently wrote that it is merely an assumption that all artists have the vibrato nearly all the time. This state of affairs suggests the necessity of setting up a series of control experiments to find out just what the situation is when a vibrato is not heard in artists' voices.

It was not difficult to find observers. One of them could not discriminate pitches a half-step apart. To such a crude aural mechanism the vibrato would be as perceptible as sights behind one's head. The others, however, had fair to middling pitch discrimination, but found it difficult to analyze a tone. It became evident that they were judging the vibrato not as tone fluctuation but as tone quality. Voice teachers have accounted for good tone quality in terms of resonance in the cavities of the head, but here was a tone quality which was due to variations in the tenseness of the vocal cords.

The psychological principle that fast variations in a train of sound waves may fuse in perception and are then interpreted as tone quality, was determined by the simple expedient of sounding different vibrato cycles from the time-honored laboratory siren. If dissimilar vibrato cycles were sounded, the observers reported that the tones were different in quality (timbre), yet actually the forms of the sound waves—upon which quality theoretically depends—were precisely the same. At first these observers could not analyze a vibrato out of a tone, but after training they all became proficient. It was a question of substituting one habit of hearing for another.

Paradoxically, it is just as great a sin to analyze a vibrato as not to analyze it. Trying to hear the actual half-step limits of a vibrato is fatal to beauty. It is getting up too close. What in a masterpiece viewed at a distance fuses into a beautiful effect, upon close inspection becomes tawdry daubs. Dissecting the vibrato into its two pitch limits destroys the auditory fusion. A certain way to have a disagreeable evening at a concert is to listen for a vibrato. When it is subjectively jerked out of its proper place in the background, it is an entirely different piece of mental furniture.

To analyze or not to analyze—when? When discussing the vibrato, or studying it, it is necessary to know what is being talked about. When enjoying a voice, ignorance is bliss. The further the vibrato is auditorially submerged, the better.

The vibrato analyzers are of two groups. The one trains himself to hear a vibrato only when he wills it, while the other can not help hearing it. A compliment for the extinguishers! Because of fine sensitivity and keenness of their ears, some hear the vibrato as a shaking just as surely as they can detect the slightest sharping or flatting. Fusion for them is more difficult than with a less accurate ear. Possibly this accounts for the attitude of Meyerbeer, Auber and Gounod. But the sensitive ear is rare, and so a vibrato heard as a wobble is rare.

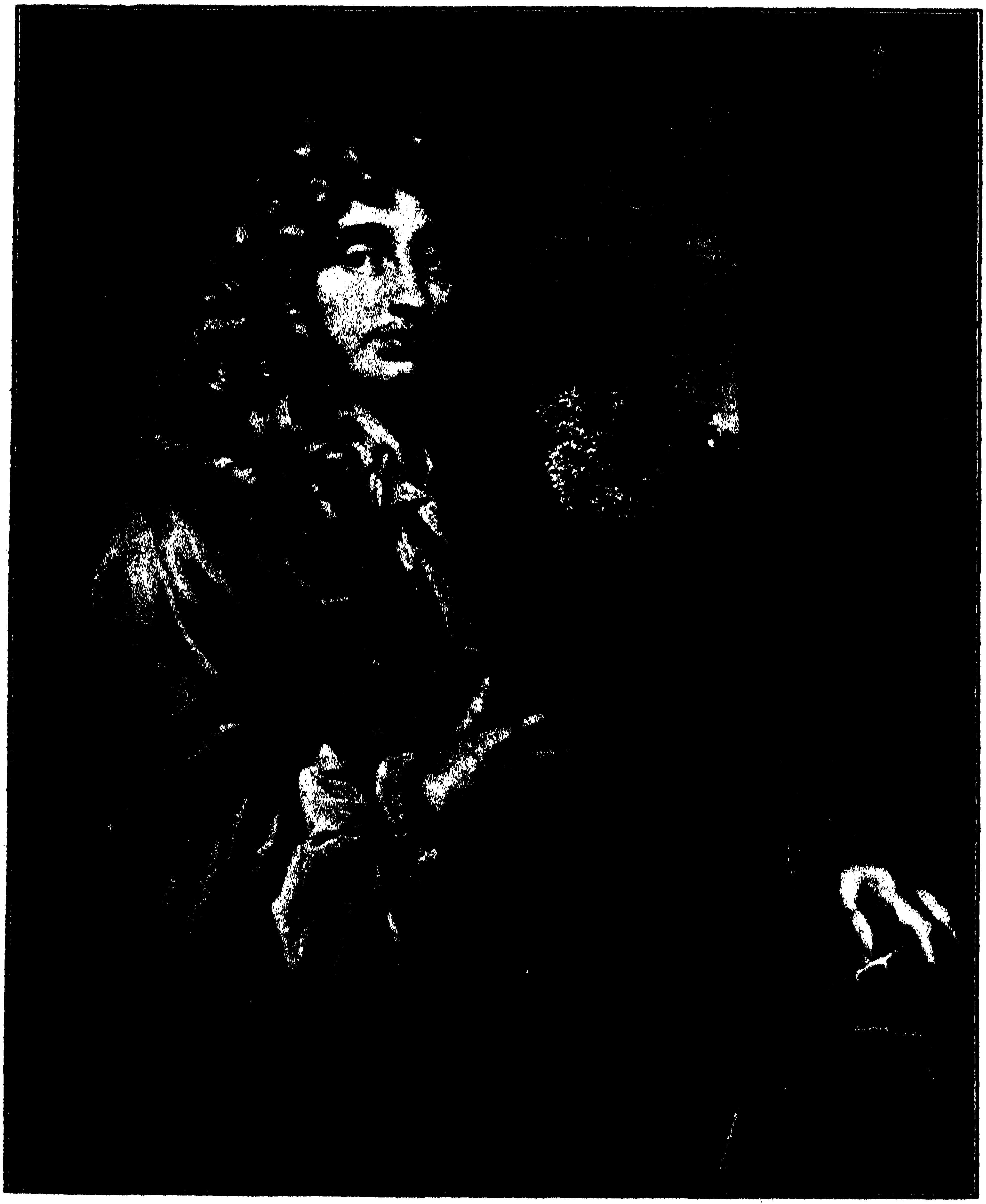


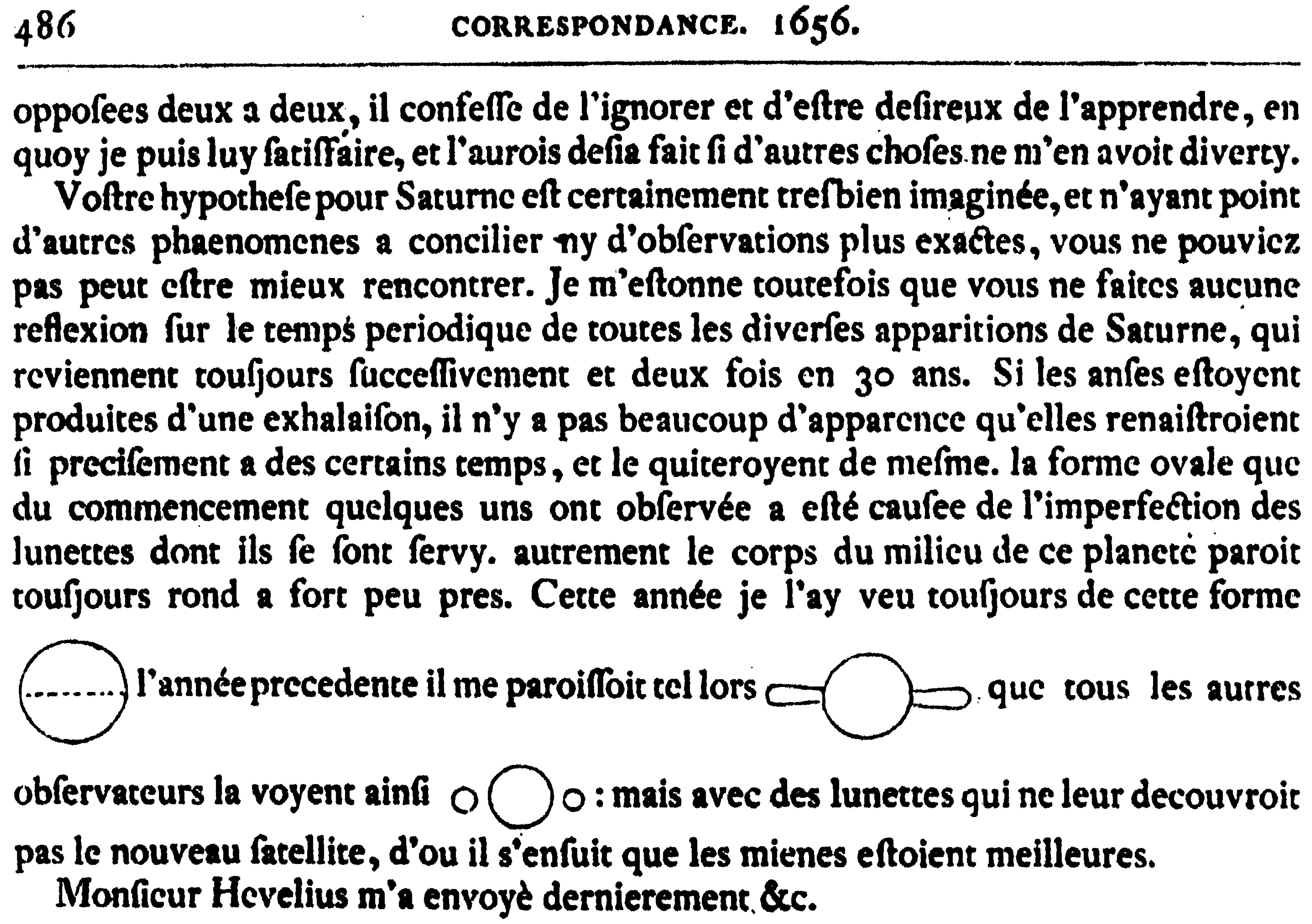
FIG. 1. CHRISTIAAN HUYGENS, BORN APRIL 14, 1629.

CHRISTIAAN HUYGENS—(1629-1695)

By Professor FLORIAN CAJORI
UNIVERSITY OF CALIFORNIA

THE year 1929 brings the three hundredth anniversary of the birth of Christiaan Huygens, of Holland, one of the greatest mathematicians, physicists and astronomers of the seventeenth century. His father, being a poet and statesman, marked out for him a literary and diplomatic career, but his early love for the exact sciences overruled that decision. Endowed with great imagination, great mathematical power and with a penetration and freshness of intellect which abided to the end of his life, Huygens contributed not only views fundamental in the philosophy of science, but also inventions of importance in everyday life. His earliest publications were mathematical in character—the determination of the area of a figure with the aid of its center of gravity, the theory of probability and the invalidity of certain pretended quadratures of the circle. Debates on the latter topic made him widely known, though he was still very young.

He perceived that observational astronomy needed for its advancement better telescopes and better clocks. He succeeded in improving both. Working with his brother Constantijn, he, in 1655, devised a superior method of grinding and polishing lenses. With a new telescope of improved definition, he discovered a satellite of Saturn, now known as Titan, the sixth Saturnian moon in order of distance. In the same year he made a second important discovery, namely, the determination of the true form of the abnormal appendages of Saturn. Galileo, to his amazement, had seen Saturn through his imperfect telescope "threefold." Hevelius saw it in three parts. Fontana made drawings of Saturn widely distorted. Modern students have little idea of the observational difficulty encountered by seventeenth century astronomers working with telescopes exhibiting distorted, colored and blurred images. The age of the achromatic lens had not yet arrived. The subtilty of the puzzle was enhanced by the change in appearance of Saturn when viewed from different relative positions of Saturn and the earth, as they revolved in their orbits. In 1655, Huygens drew Saturn as a sphere with two handles or arms on opposite sides and extending in opposite directions. When Saturn was near the sun, in January, 1656, the arms disappeared. The manuscripts of Huygens contain scores of drawings of the planet as seen at different times. He noticed a periodicity in the shapes which Saturn assumed. His constructive imagination supplied him with what seemed to him the correct explanation. To secure priority of discovery and yet allow him time for full verification, he made an announcement under the veil of an anagram, and not till four years later did he publicly explain his anagram. In a letter (August, 1656) to Roberval, he drew three Saturnian forms, shown in Fig. 2. His anagram was a Latin sentence which in translation is: "It is surrounded by a slender flat ring, everywhere distant from the surface, and inclined to the ecliptic." Thus the "handles" were recognized to be an encircling ring. Huygens entered upon the improvement of telescopes again, a quarter of a century later, and he developed the so-called "Huygenian" type. The magni-



486 CORRESPONDANCE. 1656.

oppoſees deux a deux, il confeſſe de l'ignorer et d'eſtre deſireux de l'apprendre, en quoy je puis luy ſatiſfaire, et l'aurois deſia fait ſi d'autres choſes ne m'en avoit diverty.

Voſtre hypotheſe pour Saturne eſt certainement treſbien imaginée, et n'ayant point d'autres phaenomenes a concilier ny d'obſervations plus exactes, vous ne pouviez pas peut eſtre mieux rencontrer. Je m'eſtonne toutefois que vous ne faites aucune reflexion ſur le temps periodique de toutes les diverſes apparitions de Saturne, qui reviennent touſjours ſucceſſivement et deux fois en 30 ans. Si les anſes eſtoyent produites d'une exhalaiſon, il n'y a pas beaucoup d'apparence qu'elles renaiſtroient ſi preciſement a des certains temps, et le quiteroyent de meſme. la forme ovale que du commencement quelques uns ont obſervée a eſté cauſee de l'imperfection des lunettes dont ils ſe ſont ſervy. autrement le corps du milieu de ce planete paroit touſjours rond a fort peu pres. Cette année je l'ay veu touſjours de cette forme l'année precedente il me paroiſſoit tel lors que tous les autres obſervateurs la voyent ainſi : mais avec des lunettes qui ne leur decouvroit pas le nouveau ſatellite, d'ou il s'enſuit que les mienes eſtoient meilleures.

Monſieur Hevelius m'a envoyè dernierement &c.

FIG. 2. FROM A LETTER OF HUYGENS TO ROBERVAL (AUGUST, 1656), CONTAINING DRAWINGS OF SATURN AND ITS RING, AS SEEN BY HUYGENS AND OTHERS.

fying power is measured by the focal length of the object glass, divided by the focal length of the eye-piece. Huygens and his brother Constantijn increased the magnifying power by enormously increasing the focal length of the objective. He presented to the Royal Society of London three lenses having focal lengths of 123, 170, 210 feet, respectively. It being impractical to construct tubes of such great length, Huygens discarded their use and adopted for nocturnal observation the "aerial" telescope (Fig. 3); the objective was mounted on a high pole and set in line with the eye-piece by means of a cord, but it was found difficult to get the eye and object glasses *married* or brought parallel to each other. Huygens promoted accurate observation also by the invention of the micrometer, and of the pendulum clock (an honor which he must share with Galileo). See Fig. 4, I. He worked out the mechanics of the pendulum in that wonderful book, the "Horologium oscillatorium," written in 1665 and first printed in 1673. On June 16, 1657, he presented a pendulum clock to the states-general. He suggested a pendulum vibrating seconds as a unit of length. As the ordinary pendulum vibrates somewhat faster when swinging through a smaller arc, Huygens developed the cycloidal pendulum (Fig. 4, II) which is theoretically free from that defect, but proved to be incapable of accurate construction. This pendulum is perfectly isochronous. Its point of suspension coincides with the point where the two cycloidal jaws meet, and the suspending thread touches the jaws so as to be tangent to them. The effective length of the swinging pendulum is the distance of its center of oscillation, not from the point of suspension, but from the point of tangency. Thus the vibrating pendulum has varying effective lengths. It is shortest at the

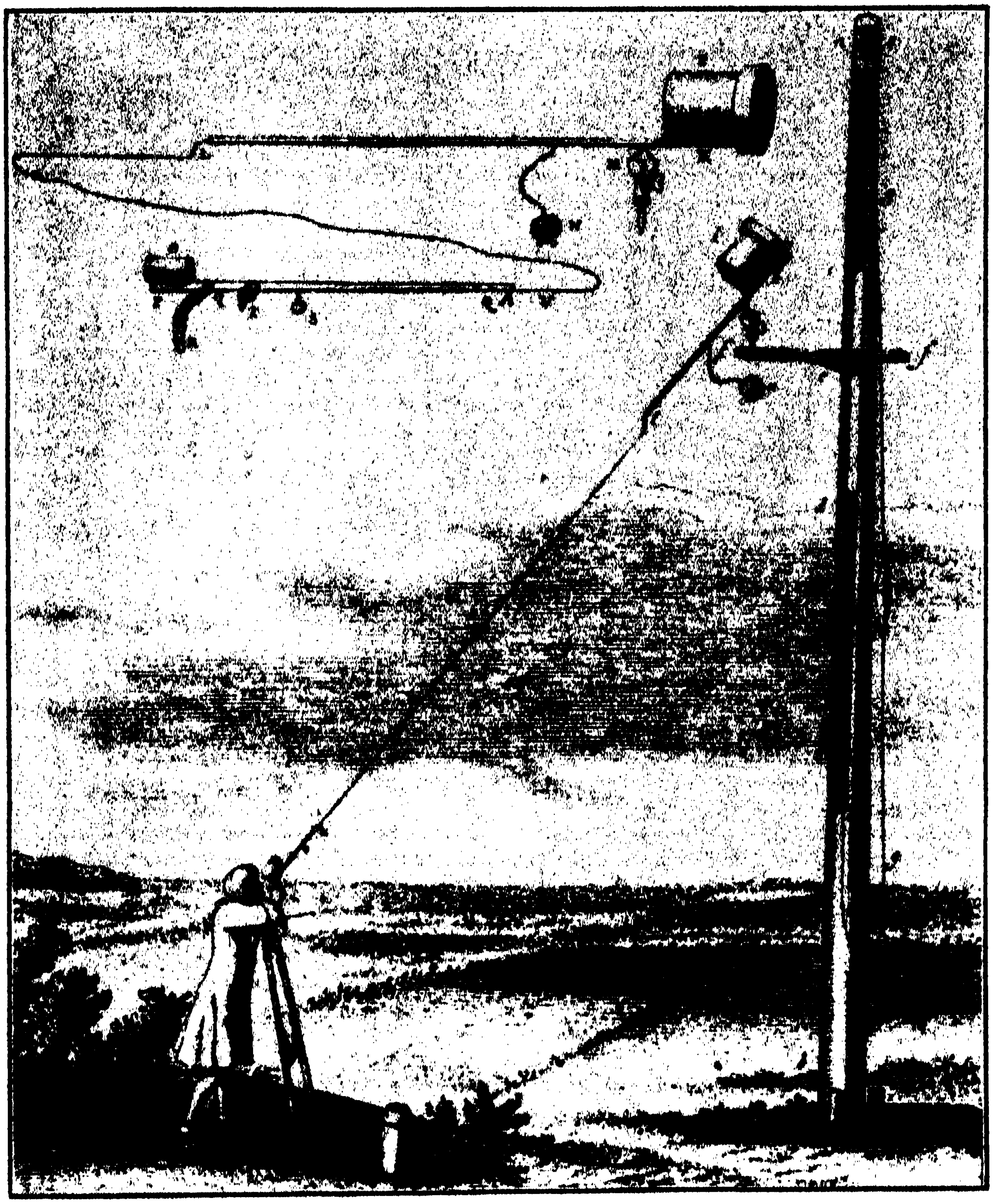


FIG. 3. HUYGENS' "AERIAL" TELESCOPE

extreme ends of its swing, and longest in its vertical position. These changes in length due to the cycloidal arcs are exactly what is needed for isochronism. Huygens invented for the practical needs of mankind the spiral watch-spring.

His astronomical observations, his improvements in time measurements, and mathematical publications gave him a wide reputation. He visited France and England in 1660, and again in 1663, when he was elected member of the Royal Society of London. That society invited attention to the investigation of the laws of impact, and received complete solutions from Huygens and also from Wallis and Wren. Thus was established the third law of motion, previously not fully understood. Huygens worked out the mechanics of circular motion and of centrifugal action. Newton was greatly assisted by these important results and spoke of Huygens in terms of highest admiration.

When Colbert, the far-sighted minister of finance of Louis XIV, invited Huygens to Paris to become member of the newly organized French Academy of Sciences, he accepted, and retained this

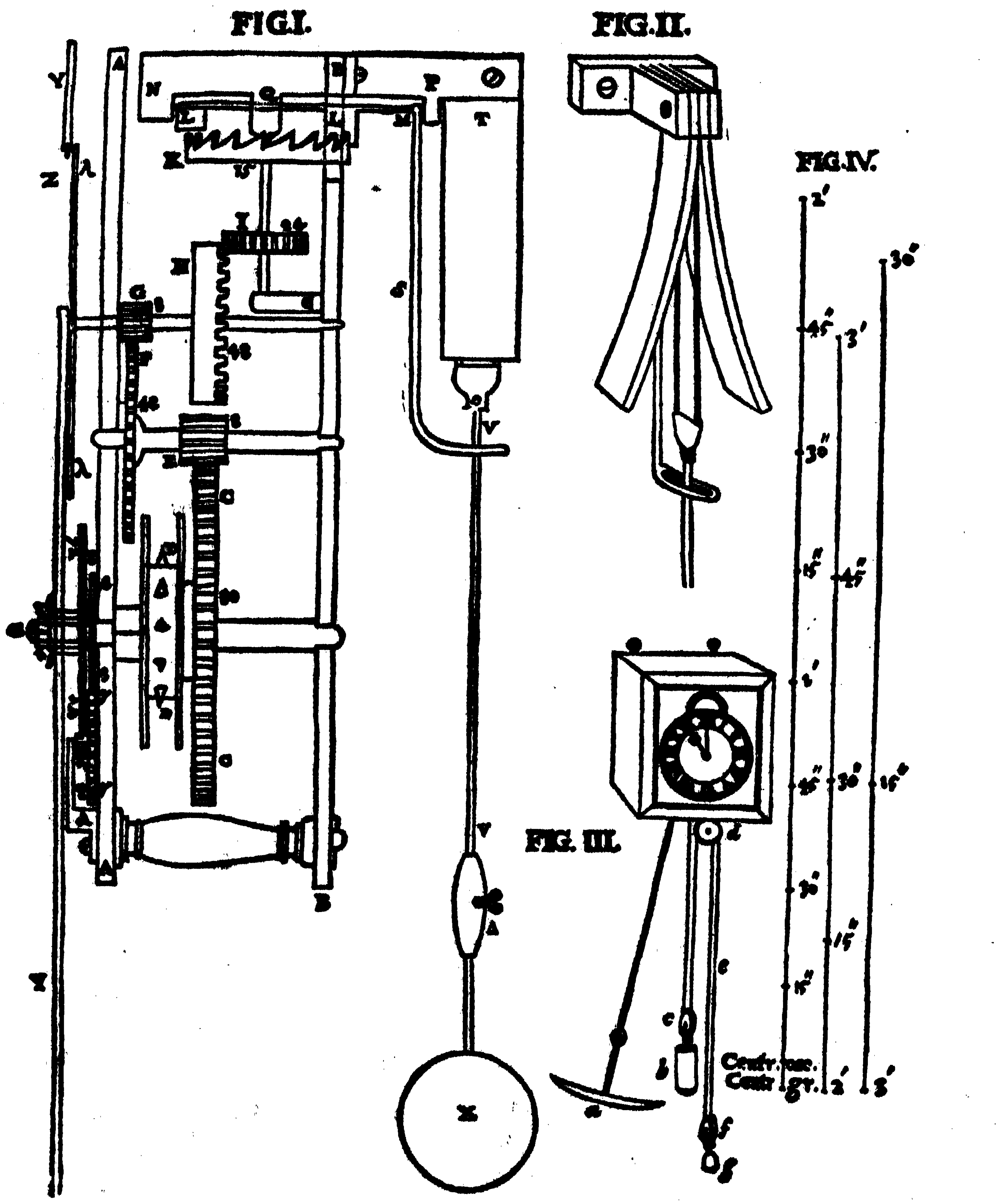


FIG. 4. HUYGENS' PENDULUM CLOCK, AND THE CYCLOIDAL PENDULUM.

honorable position from 1666 to 1681, when he returned to his native country. His return is said to have been due, in part, to ill health, and in part to the edicts against the Protestants. It was in 1678 that he advanced the great "wave theory of light" and postulated the existence of a luminiferous ether. This research was not printed until 1690. Such a theory had been suggested by Robert Hooke, but Huygens developed it more fully, explained the motion of a wave by the formation of partial waves at all points of the wave front ("the Huygens principle") and found an explanation for the reflection and refraction of light. However, Huygens did not clearly set forth the phenomenon of interference; that was done later by Young and Fresnel. It is

well known that Newton advanced a rival theory of light, the "emission theory," which in the eighteenth century superseded the wave theory, but which in the nineteenth century was itself superseded by the wave theory. In the present century both theories are coming to the front, no longer as rivals, but, apparently, under the more general view-point of "wave mechanics."

The mind of Huygens remained receptive to new ideas to the last. When Newton's "Principia" appeared in 1687, he examined it minutely and fully accepted Newton's explanation of planetary motion. He had been an adherent of Descartes's theory of vortices, but he was probably the earliest continental scientist to abandon Descartes and publish adherence to Newton's celestial mechanics. However, he did not accept Newton's view that gravitation was a property of matter and in that respect he, and Descartes before him, indulged in speculations that were almost uncanny. In this negation they anticipated Einstein. Huygens endeavored to explain the cause of gravity, in which he failed, as did Newton and every one else. A posthumous publication of Huygens, the "Cosmotheoros," indicates that he had indulged in another speculation which has become of great interest to the twentieth century public, namely, the question concerning inhabitants of the planets. Richard A. Proctor tells us that, as an expression of the pleasure derived from reading this book, Dr. Thomas Plume in England founded the Plumian professorship of astronomy at the University of Cambridge.

PHYSICS IN INDUSTRY AS A CAREER

By Dr. ROBERT W. KING
EDITOR, BELL SYSTEM TECHNICAL JOURNAL

There is a world of difference between *physics* in industry and *physicists* in industry. After a physicist gets into industry, his career often ceases to be in physics. It is in a sense axiomatic, and yet it will bear frequent repetition, that industry tends to distribute its men in such a way that each individual can make his most valuable contribution. In the case of the physicist, this frequently turns out to be in some field divorced from research but in one, of course, in which his training and knowledge of physics are of conspicuous value.

In a very real sense every industry is a biological experiment. Like the microscopist who is extracting protoplasm from a cell or juggling its chromosomes, also is the industrial magnate who is putting into practice his schemes of organization and division of labor studying biological principles. In one case, the organism under investigation is a single cell, perhaps a tenth of a millimeter in diameter. In the other case, it is an organism which may comprise tens of thousands of human beings, each of whom is one of its biological units; and the organism as a whole may extend throughout the nation or even be of international scope.

Internally the fundamental problem of each business is to build up an employee body, the members of which are so chosen for talent and training in their respective fields that they will cope with the problems of industry as a single individual whose mind embraces all pertinent knowledge. In the large industrial organization the research

laboratory, of course, plays an important part. Industrial research problems are so broad to-day as to call for the collaboration of experts in many lines, and the large laboratories developed to cope with these problems not infrequently include physicists, chemists, electrical and mechanical engineers, mathematicians and design experts. The members of such a staff constitute more than the proverbial happy family. Intellectually they are the brain cells of a "super-organic" being.

To illustrate the cooperative effort of such a corps, consider the development of the machines that establish central office connections in the dial telephone system. To one who has had no association with this apparatus it is quite impossible to picture its complexities. A simple machine-switching connection requires the making and breaking of some 1,400 relay contacts, and a single circuit would take a blackboard of a good-sized classroom for its delineation. The work of designing the circuits has of course been divided among many men and the design of the apparatus among many more.

Nor have contributions to the system been confined to electrical and mechanical experts. The mathematician, for example, has been indispensable. Dial telephone apparatus is expensive, and is therefore so designed and installed as to handle the maximum number of calls. Thus the load-carrying capacity of each piece of equipment through which a call in turn passes must be proportioned to the time interval during which the call keeps that piece busy. Likewise, in determining the proper amount to install in a central office many intricate problems in the theory of probabilities arise to which a small corps of mathematicians give most of their time.

And to the ensemble of solutions, the physicist has contributed his share, for example, in the design of a wide variety of slow- and quick-acting relays. Some of these are given the lightest of moving parts while others are supplied with heavy copper collars in which eddy currents impart just the proper degree of sluggishness of operation. The wise choice of magnetic materials and the development of new magnetic alloys have also played their part. For one man to have solved all the problems which the development of the dial telephone system has involved would have required not one but many lifetimes.

It is unnecessary to contrast in detail this manner of working with that of university research workers to show how different the two are. Let us pass on instead to a fuller inspection of research in industry.

This will disclose the real difference between pure and applied research, and —in a measure—the origin of considerations concerning patents and corporation policy affecting publication by its employees. We shall also understand the need of that quality for which all industries are ready to pay the highest rewards, namely the talent for organizing and guiding the efforts of others. There are, moreover, the rules of industrial research arising from its basic economic and commercial aspects. This in turn has a direct bearing upon the matter of initiative and the opportunity for individual freedom in choice of problems in industrial research.

The French physicist Biot once declared of the scientists of his period that their science was not the more apparent for their want of literary culture. We might paraphrase this by saying of present-day science that it need not be the less apparent when associated with industry. The mental attitude of the research worker in industry should be no different from that of his academic confrère. In general, it would be fatal

to the success of industrial research if those who are responsible for its management were guided by any other motive than a search for all the information that their skill is capable of bringing to light. Every one who has had experience in industrial research can call to mind cases that illustrate this point—cases where certain avenues were not followed because they seemed of less promise from the standpoint of useful application, only to have certain aspects of the art change shortly thereafter, so that the investigation which was abandoned in favor of another would actually have been the more valuable.

As an intellectual pursuit there need be no doubt in any one's mind but that applied research is the peer of pure research. They must necessarily deal with the same facts of nature in the same way; the same appliances for investigation and the same logical processes are employed in each. They overlap in subject-matter, and—with a frequency that is now taken largely as a matter of course—the frontiers of our knowledge are pushed forward by the discoveries of the industrial scientist. There is, however, a single fundamental difference between these two fields of endeavor. It is, as I have intimated, a difference of motive. The incentive behind pure research is the joy of discovery; the incentive behind applied research is to harness one or another of nature's forces and apply it to man's needs.

While this statement is broadly true, it does not of course follow that every one engaged in industrial research is working upon the frontiers of our knowledge. A research organization of which this could be said would not be a balanced body of workers from the industrial point of view. Actually the number engaged in advancing scientific outposts is necessarily much smaller than the number devoting their time to practical applications. There is also the chance that the status of the individual worker will shift from the field of investigation to the field of application.

Since the motive behind applied research is that of advancing an industry, the decision to make disclosures and to publish the results of investigations can be made only after proper protection has been obtained. Fundamental to all publication is the work of the patent solicitor, who must first satisfy himself that the competitive interests of the industry are being protected. Publication in advance of the filing of patent applications nullifies these and allows the world generally to profit equally with the industry itself by the results.

It seems to be the general policy in industrial laboratories to place the protection not upon the research staff, but upon a special group of patent attorneys whose business is to keep themselves well informed regarding all developments and progress. Naturally they try to do their work so expeditiously that little delay intervenes between the completion of a research program and the publication of its findings.

It might be remarked parenthetically that we have here an instance of pure science borrowing from the methods of applied science, a phenomenon which has been rare in the past but is likely to occur more frequently, for some of the methods of applied science have much to commend them. Some of our universities now maintain on their staffs a patent expert to keep in touch with the programs of faculty research and apply for suitable patent protection, to the end that whatever of practical value the patents may have will return to the institution to augment its funds for investigation.

There are other figurative elbows, the rubbing of which makes the physicist in

industry realize that he is not so much an individual as a member of an organization. Academic research, individually conceived and conducted with little or no assistance from satellitic graduate students, presents a strong contrast to the research method of industry. The university research worker generally considers—and the world is quite willing to agree with him—that he is working on his own time. Unfortunately there is little interest on the part of society as to whether he is spending his time as usefully as possible. Under these circumstances it is natural to find him constructing and adjusting all of his data, even though these might be performed as well by some one of considerably less research ability. Perhaps it would not be wide of the mark to estimate that the average academic research worker gives half of his time to jobs which might be safely entrusted to assistants were the arrangements such that satisfactory help could be hired.

The practice in industry is naturally very different. To the business world research is distinctly a money-making or money-saving matter. When industry hires a physicist it expects him to follow his profession throughout the working day, and to spend as little as possible of his time on the kind of jobs our graduate students have so appropriately dubbed "plumbing." If his work is of such a character that any of it can be delegated to those occupying less favored positions on the payroll he is expected to avail himself of their services. Indeed, so far as his advancement is concerned, it may count somewhat against him if he does not, or shows that he can not, so organize his work as to avail himself of the services of others. The industrial physicist in a sense constitutes the higher brain cells of a group of workers who look to him for their guidance in such matters as lie beyond their knowledge. He must supervise the planning and thinking of the group reporting to him, and to the best of his ability focus their efforts upon the problem which he has in hand.

At this point it is natural to ask how the physicist and the group under him come into possession of their problems. It goes almost without saying that the majority of the staff of an industrial laboratory must be working on problems whose outcome, if successful, will be applicable in important ways to the commercial activities of the industry. This of course implies that all research work in progress has the sanction of those executives who in the end will be held responsible for its outcome. It is not possible, however, to give any rule as to the origin of individual problems and even larger research programs. These may arise as a natural outgrowth of changing commercial conditions or they may represent a forecast of future requirements made anywhere up or down the line of organization, but undertaken of course with the approval of those higher up. It is not far of the mark, however, to say that the physicist in industry may at times prove as valuable for his suggestions regarding promising fields of investigation as for his skill in unraveling an answer once the problem has been agreed upon.

In the prosecution of his investigations the scientist in industry should not and does not ordinarily feel overconstrained. On this point I might quote from Dr. H. D. Arnold, director of research of the Bell Telephone Laboratories:

> To attempt to order in advance the detailed conduct of a problem would be undesirable and futile and would indeed violate the very spirit of research, which is one of self-reliant adventure along uncharted paths. Any proposal to limit too closely the initiative of the experimenter is bad, and its adoption would be certain to impose upon results the fallacies inher-

ent in prejudgment. Nevertheless, a broad and careful consideration must be given to each research at its inception, for the course of experimentation is long and costly and not to be lightly attempted.

Life in an industrial laboratory may in a sense be compared to life on a military front where the scene of active fighting swings to and fro. At any moment the order may be given to advance against some unknown sector. There may be some definite time-element involved. There will probably be numerous conferences with other laboratory groups, so that all information becomes common information. Progress may prove fast or slow, but the experience has its thrills which are in no way lessened by the practical importance attached to the outcome. After months or sometimes even years of strenuous work, one department, upon the completion of an active program, may settle back into comparative calm, frequently leaving to those who were but recently straining every nerve sufficient leisure to plan attacks upon lateral problems uncovered in the course of the work and which for one reason or another seem worthy of further study.

This brief consideration of the industrial scientist's relation to his problem forms a logical point of departure for a consideration of his relation to the organization of which he is a part. The necessary collaboration can be fully realized only through conscious and willing effort on the part of each member of the staff. The executives do not, of course, effect the collaboration; they can do little more than indicate its proper channels. The individual himself is primarily responsible for harmonizing his work and also his manner of working with that of his associates. The industrial worker is naturally immersed in an atmosphere of teamwork, and he is expected to make such contributions to the general program as the division of labor has assigned to him and his staff.

To most people the cooperative spirit that pervades industrial work is quite enjoyable. There are a few features, however, which may at times call for a philosophical attitude. Thus, after a development problem has been divided among several experts and each has made his contribution, it frequently does not prove practicable to publish a paper or papers bearing the names of all the collaborators, and some who have made important contributions may remain unnamed. In such a case the individual naturally does not have his contributions recognized at once by the world at large. But he can comfort himself with the thought that at least his superiors—and the payroll department—are not likely to be ignorant of what he has done.

Doubtless the physicist in industry is more remuneratively rewarded than his brother in the university. Among the reasons which may be ascribed to account for this condition, one factor, and to the speaker's mind an important one, is so seldom alluded to that it will be discussed here. It is a natural consequence of the cooperative effort which characterizes industrial research that a single individual may make contributions much more valuable than any which he could make if a lone worker. A hand or ear or eye by itself would not be much sought after—outside a medical college—but when these are integral parts of a Faraday or a Kelvin it may be worth society's while to bid quite high for them. Briefly, what those industries are doing which are engaged in scientific work is building composite Faradays and Kelvins whose breadth of understanding is approached by no single person and who are eminently competent to cope with the tremendously complex problems that industry gives rise to.

I do not wish to imply that an organization man is always more strategically situated than the detached person in respect to the value of the contribution which he can make to society. It is easy to cite the cases of celebrated lawyers, doctors and engineers upon whose individual contributions the work has stamped large pragmatic values. This means that the opportunity does arise in which the gifted individual can accomplish important things single-handed. But such cases in no wise tend to disprove the thesis that the more closely the efforts of the average worker tie in with those of others the more valuable do his efforts become.

An illustration chosen from the domain of physics may be of interest. The amplifying device known as the telephone repeater is becoming of greater and greater importance in our plant because of the increasing demand for long distance facilities. The familiar three-electrode vacuum tube forms the amplifying agent of the repeater. For telephone work we have always employed an oxide-coated filament, because it has reduced what we might term the "cost of electrons" well below that obtainable with any other known type of filament. We were not satisfied, however, with the oxide filament because it was the best then known. There seemed reasons for believing that it might be further improved. Ten years ago the repeater tube consumed over five watts in the filament and had an average life of 1,000 hours. This is very satisfactory considering even the best radio tubes of to-day. To-day, however, the telephone repeater tube consumes two watts in the filament and has an average life well over 25,000 hours, and yet gives as abundant a supply of electrons as its predecessor. Translating this investigation in the field of thermionics into money shows a saving to the telephone business of this country of about five million dollars a year.

The filament investigation can be used to illustrate other outstanding characteristics of industrial research. As just stated, the study of filament coating extended over a period of ten years. It would be hard to say how many persons participated in it, or how many thousands of tubes were made and studied during this time, but the cost of the program averaged somewhere in the neighborhood of $200,000 a year, so that its total cost was about two million dollars. This program was launched and funds authorized by the executives years before there was any basis for definitely foreseeing a successful outcome.

It would be difficult to conceive of such a change in the conditions surrounding academic research that a program of this kind could be carried out under university auspices. Nor is there any reason why it should be so conducted. The investigations were not particularly fruitful from the standpoint of new principles uncovered. There was little of the kind of work in them that we find described in the leading journals of physics. Of course, new principles might have been uncovered or some striking new discovery might have been made. This, however, was not the purpose of the investigation, and no one feels that it in any sense failed or miscarried because such an outcome was not realized.

The enormous value of specific research jobs to industry naturally leads us back again to the scale of compensation upon which industry rewards the individual scientist or the small group whose contribution proves to be measurable in millions of dollars. On this point I can speak with complete assurance only for the business with which I am best acquainted. Those of you who read the advertisements of the Telephone Company know that it claims to have made no millionaires. This in part answers the question. The men who developed the vacuum tube filament just

referred to did not profit to the extent of several millions, nor would any one seriously maintain—least of all themselves—that their reward should have been commensurate with the value of their contribution. This would have involved unjustifiable exploitation of the telephone-using public. The millions upon millions of dollars which scientific research, as carried on within this industry, has saved belong rightly to the public, and are being returned to them, partly in the form of better and more extended service and partly as reduced rates. This I believe to be the attitude which industries in general adopt toward the public which supports them.

In a sense, of course, salaries like everything else in the business world are determined by the law of supply and demand. However, no direct appeal is made to this law in establishing salary levels. One thing that industry is trying more and more to protect itself from is labor turnover, and nowhere is this policy of greater importance than in the administration of a scientific staff. The result is that, in general, such staffs are well paid and supplied with stimulating working conditions.

Scientific research both pure and applied have never flourished as they do to-day. Applied research stands nearer the coffers and treasuries, and in the matter of money for salaries and equipment occupies the favored position. For this reason, together with the fact that it has proved a most successful money-making venture, its growth has perhaps been accelerated beyond that of its companion. This situation is viewed with apprehension by some who have the interests of pure science closely at heart. I believe we may affirm, however, that the opposite and optimistic view is the correct one. Although applied science draws its money from industrial treasuries, it draws what we might call the vitamin ingredients of its diet from pure science, and the economic forces which are propelling industrial research at its present prodigious rate must in turn insure that the source of its prodigy's life-giving elements does not languish. An important movement to this end with which the names of the National Research Council and the National Academy are associated is already under way. This may well be the nucleus of a nationwide mechanism suitable for transmitting to pure science the contributions of an appreciative commercial world. Several of our leading industries have already recognized their indebtedness to pure science by large contributions to the National Academy fund. Are we not on the threshold of a new era when our universities and industry will walk shoulder to shoulder, looking upon each other as equally important participants in the world's greatest undertaking?

OCEAN PLANKTON AND PLANKTON PROBLEMS

By Professor WINFRED EMORY ALLEN

SCRIPPS INSTITUTION OF OCEANOGRAPHY OF THE UNIVERSITY OF CALIFORNIA

DEFINITION OF PLANKTON

PLANKTON is a vague term invented by Hensen in 1887 to include for convenience in discussion all organisms suspended in sea water without powers of changing locality by the efforts of individual components. The original definition emphasized flotation, and the most common usage at present follows this line of emphasis with supplementary qualification by expressions such as "weakly swimming" and "passively floating." As a matter of fact this emphasis on flotation and passivity is likely to convey a wrong idea as to the characteristics necessary to include an organism under the convenient heading which is intended to cover all of those not sedentary on the one hand and not actually or potentially migratory or itinerant on the other hand.

Indeed, it is readily apparent to any one familiar with plankton that many zooplanktonts (*e.g.*, arrow worms) swim with power and speed exceeding that of most fishes. But their size is so small that they have to swim many times their own length to traverse a foot of water, and the utmost distance covered in a day could be passed in a few minutes by many fishes. Far removed from the arrow worms in almost all ways are the large jellyfishes which are much larger than most fishes (extending over ten or fifteen feet) but which can move their great bulk probably less distance in a day than an arrow worm can move itself. As regards passivity, perhaps diatoms furnish the best examples and the smallest size of planktonts may be found in the bacteria.

Amazing as these differences in the components of the plankton may be there are others just as great. In the cycles of marine life some planktonts are builders (synthesizing plants) and some destroyers (predatory animals). Some are hunters, others parasites and others scavengers. Some are innocuous to neighboring organisms, while others are poisonous or otherwise injurious. Some are temporary and some are permanent in plankton membership. Amongst temporary planktonts most kinds are planktonic in embryonic or immature stages, but some are planktonic only in mature stages. Most of the orders of plants below the Bryophytes are represented in the plankton in some way or other, and all of the phyla (branches) of the animal kingdom have some kind of representation in it.

In consideration of the broadly intricate relationships thus sketchily suggested it may be obvious that only two criteria can be applied in identification of plankton and that they are not capable of exact delimitation. These two criteria are free suspension in the water, and lack of capacity to control their locality of occupation.

If any one supposes that free suspension is a criterion which always can be applied precisely he need not go far to discover his delusion. I strongly doubt that any student of plankton is able to distinguish certain very early larval stages of whale barnacles from similar stages of many other crustaceans, some of which may belong to the permanent plankton. Still less do I believe that any one would be able to say that a larva ready for attachment to its whale host is clearly planktonic in character. It may be caught in his net because no whale host is within reach, but its real

character is that of a fixed parasite. Still more difficult would be the cases of some of the parasitic copepods and some of the parasitic worms, especially some of those less specialized, which might leave one host for another and be captured in transit. Similarly confusing are the cases in which one small organism fixes itself to a true plankton organism either temporarily or permanently. It is not freely suspended (or "free floating" as stated by some definitions). On the other hand it would be palpably absurd to ignore its presence in the plankton population.

"Lack of control of locality" is the term which I have adopted to cover the idea that "plankton" includes those organisms at the mercy of their inanimate environment, helpless to avoid aimless drifting in moving water or indefinite detention in still water. There are two major difficulties which may appear when attempting to apply this criterion: first, what extent of movement permits inclusion; second, how may it be known when development of an immature organism has carried it beyond this limit of inclusion?

Concerning the extent of movement it is pertinent to inquire if a rate of transit of one mile per hour would exclude an animal from the plankton group. Or should the limit be placed lower or higher? Furthermore, how is the distinguishing rate to be recognized? Should it be necessary for the distinguishing rate to be sustained for one hour, or for any other definite unit of time? Should any effort be made to distinguish random movement from movement apparently purposive?

Concerning the point of departure of a growing animal from plankton classification one may find his practical difficulties somewhat embarrassing. A number of very small fish may be taken in a plankton net and readily recognized as belonging to the plankton group. Another catch near by may include some as easily recognized as beyond that classification. Another may include some of intermediate character. How is one to determine the line of distinction?

For certain rare cases perhaps a third difficulty may appear to have major rank, *i.e.*, when an animal apparently capable of change of locality habitually associates with and seeks the protection of a plankton organism why should it be excluded from plankton classification? For example, there are the little fishes which shelter themselves amongst the stinging threads of the Portuguese man-of-war. By habit they appear to be planktonic, by capacity nektonic (capable of choosing locality by directive movement).

It is true that in practical investigations these difficulties may rarely or never appear obtrusive. But it is none the less true that they have a positive relation to the formation of an idea of plankton as a group of things and that they can not be entirely disregarded in comprehensive attention to plankton problems.

General Aspects of Plankton Relationships

Supposing that we hazard a guess that there are not more than one thousand species of permanent planktonts (successive generations maintaining a planktonic existence through the entire lives of the individuals composing each), and not more than ten thousand species of planktonts of all kinds and degrees, still we can not ignore the fact that any one of hundreds of these species may sometimes appear in clouds that render great areas of water "soupy" or gelatinous, and that each single organism bears n intricate series of relationships to others of its kind; to other planktonts; to other inhabitants of the sea; to the physical and chemical characteristics of the water, of the air, of the sea bottom, of the coast lines and of the land; to topography and geology of the region; and to

solar radiation and other astronomic influences. In other words, the fundamental problems of the plankton are not only profoundly intricate as concerns marine organisms but they are inseparable from many of the fundamental problems of oceanography in general and of cosmography.

While it is obvious that the ramifications of the threads of relationships involved in the solutions of these problems are beyond the limits of human capacity to trace in detail, it is also obvious from practical experience with problems of nature that certain figures or patterns formed by the intersections of these ramifications may be traced and the information applied in approximate solutions which serve the purpose of true solutions for ordinary needs.

Avenues of Approach to Plankton Problems

According to the needs or interests of the observer or investigator there are several different avenues of approach to plankton problems, involving more or less distinctly different statements of the problems and their elements, more or less distinctly different methods of solution and more or less distinctly different views as to the degree of approximation to a true solution which may be acceptable.

To a physical oceanographer problems of the plankton (or, indeed, any problems of marine biology) may appear to have only academic or theoretic interest or value. He may see readily enough that differences in abundance of organisms may cause differences in rate or direction of flow of certain limited masses of water, that accumulation of organisms or masses of organic remains may make significant alterations in contours of ocean basins, and that physical properties of sea water may vary under certain relationships to organisms, but he can not see that the influence of organisms is appreciable when compared with several other influences in practical operations. Therefore he rates biological phenomena as constituting a negligible factor which safely may be ignored in ordinary discussion of the oceanic mass as a whole. If attention be required for purposes of highly localized interpretations he can get along very well with exceedingly rough approximations. For example, his time units rarely need be smaller than millennia or his space units smaller than thousands of square miles or cubic miles. In most cases he does not need even to distinguish plants from animals in considering the organisms involved.

Up to a certain point the marine navigator shares the avenue of approach of a physical oceanographer, but at that point there is sharp departure when he finds that certain marine organisms are destructive to his shipping and his port equipment and that certain others are related to products valued for the opportunities they give for transportation and exploitation. So far as he is concerned the problems of the plankton are highly specific and definitely delimited. His primary interests are typically in certain temporary components of the plankton larval stages of ship worms and other borers, unattached stages of barnacles and other encrusting organisms, briefly, in those stages showing vulnerability to lethal agents or susceptibility to deterrents. But if he concludes that some other kinds of plankton organisms may yield, or help to yield, products of commercial value, he may exhibit primary interest in plankton distribution and in characteristics of plankton production and maintenance which may be directly or indirectly used for his advantage.

A commercial fisherman is likely to take no interest in plankton problems unless he can be convinced by some one that an acquaintance with plankton is necessary in order to develop and sustain the fisheries. Once convinced, his

interest may become active, but it is almost sure to be narrow. All he wishes to know is how any particular kind of plankton affects the particular kind of fish that he seeks or how his methods of fishing may be made more profitable by attention to plankton. All an oyster fisherman wants to know is what kind of plankton is used by the oyster for food and how this kind can be most effectively furnished to that mollusk. His main interest is in the possibilities of plankton culture for oyster food or in the methods of planting oysters which will give them best contact with such food. A sardine fisherman would be interested in studies which might show him how to use plankton indicators in hunting for that kind of fish, something similar to the color signs which he already uses to some extent, *e.g.*, yellow water and brown water. He would also be interested in plankton studies which might give him some clue as to whether a coming year would be favorable or unfavorable for catching these fish. Perhaps the studies which would appeal to him most strongly in some localities would be concerning what plankton animals prey upon larval sardines, to what extent their destructiveness affects the numbers of commercial size at any given period and to what extent preventive or remedial measures may be applied. But in all cases fishermen would be satisfied with broad statements of these problems and of the terms of their solution, and with rather crude studies of restricted groups of plankton.

Any geologist who pretends to an understanding of the structure and origin of enormous areas of the earth's surface to-day must give at least a little attention to plankton organisms of remote geologic time. If his work is purely descriptive or narrowly restricted to a particular type of structure (*e.g.*, lava formations) he may avoid any definite consideration of plankton, and in a great deal of geologic work plankton may be ignored or else discussed in collective terms having little significance in relation to those organisms as a comprehensive group. But one can not go far in historical geology or structural geology without definite reference to certain types of plankton. Concerning these types he is driven to inquire at once as to the actual or relative extent in space and time of their contributions to geologic structures, the methods of their making these contributions, and the influence of such contributions upon associated features of geologic changes. These inquiries lead naturally to others as to the conditions of existence of the organisms which made the contributions, the conditions which decided the location, extent and texture of the contributions, and the periodicities indicated by their present aspects. Investigations along such lines can not be made fully satisfactory without examination of the pertinent characteristics of typical living representatives of the different groups under scrutiny. (If one should wish to get the best understanding of the behavior and manner of life of a dead dog of unknown history he would study the nearest of kin observable amongst live dogs.) Prominent in this examination must be the question as to why they congregate most in certain areas, why they are absent in certain other areas and why they differ in abundance in a given area at different periods of time, long or short. Presumably, it may appear to some geologists that understanding is not complete unless attention is given to the possibilities of influence of many kinds of plankton (and other organisms) which left no permanent record but which must have played an important part in relation to the activities of those which did leave permanent record, aiding them in obtaining food or competing with them for particular necessities of life. But, however wide his investigations may go, it is not probable that a geologist will demand solutions to these problems in exact details

of small units. He is accustomed to dealing in large units of time and space and his background of millions of years and of geologic horizons inclines him to prefer inclusive statements and general units if they can be made to answer his purpose. Even an "oil geologist," who may be supposed to constitute an exception to this generalization, is primarily interested in exact determination of foraminifera and diatoms because he wants to use them as identification marks for strata which may or may not be promising for oil. He gives little attention to other features or relationships. Briefly, it may be said that a geologist's approach to plankton problems is with the definite intention to study them only to the extent necessary to give him a clue to the solution of his particular set of geologic problems.

There have been, and still are, many group specialists giving attention to marine plankton of one type or another; *e.g.*, copepods, arrow worms, pteropods, tunicates, coelenterates, dinoflagellates, foraminifera, radiolarians, diatoms and bacteria. Many of these specialists have no interest in plankton organisms except that of discovery of new species and varieties, or at least new records of occurrence. For such as these only one plankton problem exists and it is extremely simple, amounting merely to the collection of material which may be expected (or at least hoped) to yield one or more specimens "new to science." But there is a considerable number of specialists whose interests are broader. While they like to find new species and varieties and new records of occurrence, they also wish to know the local conditions which are, or may have been, responsible for these new discoveries and to understand the fundamental conditions responsible for the close similarity of representatives of known species and varieties over wide oceanic areas. Through this broader interest a few may be led to a comprehension of the need for understanding the ocean as a unit of environment rather than as a mixture of environments containing certain features capable of arbitrary separation for examination and for use in explaining phenomena exhibited by the particular plankton group. I regard this difference in comprehension as a matter of importance because it seems to me that observations on any oceanic feature (temperature, for example) are more likely to receive reliable interpretation from a biologist who regards temperature as an attribute of the oceanic whole than it is from one who regards temperature as an abstract phenomenon involved in no essential relationships to the sea. At best, the approach by one who is a specialist from personal preference will be by expansion from the investigation of his particular group of organisms to investigations of the influence of associated organisms and of chemical and physical phenomena upon the characteristics regarded as significant in his specialty. Obviously, the degree of expansion from the basis of his specialty will vary enormously with the inclinations of the investigator and with his control of resources and facilities. Theoretically, expansion might proceed along practical lines to the limits of the plankton or of the whole oceanographic field. Practically, it is generally confined to a few of the more obvious of associated phenomena and to minor excursions in their direction.

It may be surprising to some people to suggest that professional politicians may have any concern in plankton investigations or that they have seriously influenced the direction and progress of such investigations, but it is certainly true that they have taken interest and exerted influence. In practical discussion of plankton problems it is therefore pertinent to inquire as to what views of these problems influence the actions of a politician toward them. With rare exceptions his sole interest is in the

personal advantage which he may derive from attention to such problems. Usually such advantage may be obtained in one of two ways: first, by promoting some investigation favored by his constituents or appearing directly beneficial to them; second, by promoting some highly spectacular investigation which either has practical values or which can be veneered with a show of practicality. A man from an oyster-producing section would take an interest in the extent of use of plankton for food by oysters and in the possibility of cultivating some kinds of plankton to help increase quantity and certainty in oyster production. There his interest would usually end and he might be a detriment rather than an aid to investigations calculated to reveal the character and relationships of plankton as oceanic phenomena. Perhaps it is not too much to say that whatever the desiderata agreed upon by scientific experts proposing a program of investigation of marine plankton it can not be placed in effective operation until it has been more or less revised to conform to the views of one or more individuals primarily interested in its relation to their standing with the public. Evidently this is a good point to introduce an assertion (which is also pertinent to other connections) to the effect that one of the most important features of plankton problems is that including the human influences involved in their solution.

So far I have been discussing the natural avenues of approach of individuals who usually would be content with broad statements and gross terms of solution of plankton problems, or of those who would be satisfied with incomplete statements and limited terms of solution if bearing obvious or superficial relationship to some problem already holding a commanding place in their estimation. Now I wish to speak of two who (theoretically at least) have so much in common that their approaches must be almost identical and their differences must be found mainly in the characteristics of materials handled and in the consequent modes of operation. I refer to the chemical oceanographer and to the biological oceanographer, the latter of whom, with equal propriety, may be called an ecologist.

In what way does a chemical oceanographer differ from a chemist examining sea water? Essentially in the objective toward which he strives. The chemist who examines a sample of sea water may do it as thoroughly and accurately as the chemical oceanographer, but his tendency is to be satisfied with his results and to regard his investigation as completed when he feels sure that he knows fully the chemical characteristics of that sample. Not so the chemical oceanographer. He regards the sample as merely an illustration of what could be found in a sample of water taken from the ocean at a certain time and place and preserved under a certain set of conditions. He knows that there are thousands of cubic miles of sea water which may differ from that sample in a number of interesting and important details, and he knows that a true understanding of the oceanic mass as a chemical mixture can be obtained only by detailed examination of all parts under all of their circumstances of existence. It does not matter that he realizes the impossibility of reaching that objective, because every step that he takes toward it brings vast returns in establishment of probabilities and in practical approach to understanding of fundamental features and of normal trends in changes of relationships. In the plankton he recognizes one of the most prolific sources of localized changes in chemical characteristics of the water as a fluid mass, and in it he also recognizes one of the most disturbing substances suspended in this fluid. He recognizes, or soon learns, that some kinds of chemical change are closely related to particular species of plankton

and that these changes may vary somewhat according to the condition of the organisms. It is evident, therefore, that he is interested in small units; in daily or hourly changes, in species or even varieties, in age, in activity and in other features of plankton existence which demand close scrutiny.

The biological oceanographer reciprocates most of the technical interest of the chemical oceanographer and adds some of his own. In superficial appearance his view of the ocean is somewhat different since he regards it primarily as the residence of groups of living things definitely specialized to meet its conditions. In practice this appearance tends to be lost because he can not account for numerous characteristics of structure and behavior without using the view-point of chemical and physical oceanographers. For some of his solutions of plankton problems he need not use units so small as those generally required by the chemist, but for many f them his limits must be just as rigid and just as restricted. Considering the ocean as a whole, plankton problems, no less than others of great magnitude, present certain broad features for preliminary attention. First, after finding that such things do exist in the ocean, is the problem of finding what they are, of naming them and describing them, and of classifying them so that any questions concerning them may be intelligently discussed. With such things under way or accomplished for the ocean as a whole (or for any designated part) indefinite series of questions and derivative problems crowd for attention. From these some may be selected as basic in much the same way as those just mentioned. For example, there is the question of geographic distribution: is plankton present throughout the ocean, or any designated part thereof? Then there is the question of distribution in time: is plankton always present where found (or absent where not found); is it present at all seasons of the year and for indefinite periods of years? Again there is the question of vertical distribution: is plankton found at all levels or at particular levels at all places and times? Also there is the question as to whether all components of the plankton group are alike in respect to these things and with respect to abundance in all such relations, and if not as to what the peculiarities of unlikeness may be. Having established a knowledge of normal conditions with respect to these points, it is possible to attack such subsidiary problems as those of particular relations to temperature, salinity, oxygen content, alkalinity, competing organisms, beneficial contacts with other organisms, injurious contacts with such organisms, influences affecting life histories, influences affecting abundance at different times and places, and indefinite numbers of other problems.

THE AMERICAN PLANT MIGRATION

By Dr. BERTHOLD LAUFER

CURATOR, DEPARTMENT OF ANTHROPOLOGY, FIELD MUSEUM, CHICAGO

ALPHONSE DE CANDOLLE'S famous book, "Origin of Cultivated Plants," ranks among those monumental productions of science which, although written a generation ago and on numerous points out of date, will always remain young and act as a stimulus to fresh research for generations to come. Botany and agriculture, as well as history and ethnography, have advanced so rapidly since his day that many are now qualified to add new contributions to the problems discussed by him, but no one at the present time would be able to recast his book so as to make it conform to modern progress. An alliance of many scholars—botanists of all shades and grades, agriculturists, horticulturists, archeologists, orientalists, historians, etc.—would be required to cope adequately with a task of such magnitude. Should such a plan ever be considered, it is hoped that a fundamental deficiency in de Candolle's book will be adjusted. One may peruse this great encyclopedic work many times, our memory may retain a number of facts pertaining to this or that plant, as our personal inclinations may lead us; yet no lasting impression will remain on our minds as to the significance of plant cultivations in the development of mankind.

The reason is obvious: the subject is not presented in correlation with human culture. The division of the book is purely mechanical: there are five main sections dealing with plants cultivated for their subterranean parts, for their stems or leaves, for their flowers, for their fruits and for their seeds. Under these botanical categories, the most heterogeneous plants are arranged and succeed one another, regardless of time and space, with no bond linking them together. We are thus confronted with a collection of historical essays or sketches in which subjects historically interrelated are scattered and widely separated, without any attempt at correlation, coordination or pragmatic history-writing. A wild plant is a given fact of nature; the cultivation of a plant presupposes human interference and care, and must therefore be regarded as life and movement in the long career of man. Cultivated plants are an essential element in the history of human economy and civilization, and their study must be grasped in the sense of a cultural movement. In the same manner as many other cultural ideas and inventions, plants have migrated at all periods, and continue to migrate and expand under our own eyes. The great plant-migrations mark the lines in the march of civilization even more clearly than other departments of human endeavor, because agriculture and all concomitant features represent the most stable and unchangeable factor of our economic life. In order to be significant and fruitful, the history of cultivated plants must be conceived of as the history of plant-migrations.

At the present time almost everything is almost everywhere, and we are anxious to learn whether it was there always, or, if not, how and when it has taken its place. Looking at our country, we recognize without difficulty four strata of plant-cultivations: (1) those peculiar to the aborigines of America, like maize, several varieties of bean, pumpkins,

squashes, sunflower, *Nicotiana rustica,* etc., subsequently adopted by the white settlers, who also succeeded in cultivating wild species of North America, as, for instance, the grape; (2) plants introduced from England in colonial times, like wheat, barley, rye, oats, buckwheat, apple, pear, etc.; (3) American plants introduced from the West Indies in the seventeenth and eighteenth centuries; (4) numerous plants brought over from China and Japan from the eighteenth century onward to the present day.

In countries like India and China, conditions naturally are more complex, the stratification is deeper. In China we find from the earliest times a few cultivations typically Chinese, as, *e.g.*, the soy-bean, peach and apricot; others in common with the Sino-Tibetans or Indo-Chinese, the congeners of the great stock to which they belong, like oats, hemp and many species of pulse and Allium (leek and onion); others, like wheat and barley in common with western Asia, and rice in common with southeastern Asia. From the latter part of the second century B.C. the introduction of exotic plants sets in, inaugurated by alfalfa and grape-vine brought back from Fergana by the first Chinese explorer, General Chang K'ien, and followed by a long retinue of other Iranian and west-Asiatic plants, this great Iranian plant-migration, described in detail in my monograph, "Sino-Iranica," continuing for fourteen centuries. Simultaneously the Chinese absorbed what is now southern China and advanced to Tonking and Indo-China, adopting all the useful plants they encountered in that subtropical area and amalgamating the type of southern garden-culture with their old northern plow-ox culture. The last phase of this development is signalized by the introduction in the sixteenth and seventeenth centuries of a large number of species of American origin, which added a considerable plus to the already naturalized quota, with the striking result that almost all useful plants of the universe are now embraced by Chinese husbandry.

In determining the steps in the great American plant-migration, the records of the Chinese are of fundamental importance, as no other nation has preserved fuller and more exact accounts of agricultural events and innovations. It can hardly be fortuitous that all plants without exception, which are justly regarded as American, are placed on record by the Chinese as having been introduced into their country in the latter half of the sixteenth or beginning of the seventeenth century. Korean and Japanese traditions move along the same line; and wherever documents are at our disposal, as in Siam, India, Persia and Europe, the same result is echoed from every quarter. Let us suppose for a moment that there were no botany in America, that we were ignorant of the achievements in agriculture of the American Indian and that we did not even possess the European herbals of the sixteenth century which successively describe the novel plants as introduced from the New World—even this being the case, merely on the basis of our experience with the situation in Asia, we might justly claim that, from a historical view-point, all plants like maize, several species of Phaseolus, potato, batata, manihot, tobacco, pineapple, guava, papaya, Anonas, Capsicum, peanut, agava, sunflower, cashew, arnotto, cacao, tomato, prickly pear and many more, must have originated in and hailed from America. All these cultivations and their products were a revelation to the peoples of the Old World and entirely unknown there prior to 1492.

This conclusion is further linked with my conviction of the independence of aboriginal American agriculture. None of the Old World cultivated plants is found in pre-Columbian America; on the

other hand, none of the American cultivated plants occurs in Europe, Asia or Africa prior to the age of discovery. There never was a direct prehistoric interchange of plants between China and Mexico, or between Oceania and Peru; there is not the slightest foundation in fact for such like speculations. The ingenuity and accomplishments of the American Indian in agricultural products are deserving of our highest admiration. The mere fact that the plants cultivated by the Indians had really been brought into a perfect state of cultivation as early as pre-Columbian times permitted the white man's colonization and made the propagation of these cultivations over the Old World possible; what the white man applied to them were solely improved methods of culture. From numerous biological data, as revealed by the differentiation and variation of corresponding cultivated and wild forms, it may be inferred that Indian agriculture must be not centuries, but thousands of years old.

Of all plant-movements, the American plant-migration, although the most recent, is the most extensive, the most prominent, the most universal and the most momentous in the world's history. It therefore merits profound study in every detail. It has encompassed the globe in its entirety, made its influence felt everywhere, changed the surface of the earth and brought mankind together into closer bonds. For the student of Old World agriculture it is essential to have a clear conception of these intrusions, if he is eager to know what plants originally belonged to a certain culture area.

The history of American plants is also more instructive and fascinating than that of any other plant-movement, for each American plant has its distinct and individual type of history: the migration was not a single event that might be told in a few pages, or a series of operations of a uniform character following a definite scheme, but it was a long, romantic chapter composed of an infinite variety of good plots and stories, set off from a picturesque background in a wide perspective. Nearly all the great nations of Europe assume their rôles—Spaniards, Portuguese, Italians, French, English and Hollanders. The scene is laid over a vast area stretching from the Atlantic coast of Canada, New England, Virginia, down to Florida, the Gulf of Mexico, the West Indies and Brazil, as well as along the Pacific coast from the shores of Mexico and Panama down to Peru and Chile. For the first time in history the oceans developed into a great artery of plant-communication, and plants crossed both the Atlantic and Pacific, directly to Europe and Africa eastward and to Asia and the Oceanic Islands westward. It was a world-wide crusade unparalleled in the microcosm of previous ages. The transatlantic and the transpacific migrations were almost coeval, and we face the curious spectacle that in India, Central Asia and Siberia, several American plants, notably tobacco, suddenly clashed in a sort of head-on-collision, by encircling the globe eastward and westward simultaneously.

The gifts of the New World were all of a democratic character and made a world-wide appeal; tobacco conquered all peoples of the globe without distinction, and I know of only a single tribe that does not practice smoking—the poor islanders of Botel Tobago. Tobacco is more universally consumed than any other narcotic, has profoundly influenced the economy of most nations and signally affected social customs and promoted sociability. In a spirit of gratitude, Chinese and Japanese have bestowed on tobacco the name "herb of amiability" (*ai-king ts'ao*), as they explain, "on account of the affectionate feelings entertained toward one another by all classes of mankind since its use

has become general." Tobacco has proved the greatest peace-maker of mankind and contributed in a higher degree than all pacifist movements to the tranquillity, comfort and happiness of an overwhelming majority.

Maize, peanut, batata and potato have added a considerable share to the means of human sustenance, and consequently to the wealth of nations and the increase of population, notably in those countries where the ordinary cereals are of difficult or costly cultivation. Batata and potato, in particular, are invaluable as famine crops, and in times of drought and scarcity have saved the lives of millions of people. In many parts of western, central and southeastern Asia there are numerous destitute peoples cooped up in barren mountain-fastnesses, much like the tribes in the highlands of Peru, now subsisting exclusively on maize and potatoes; and we wonder how they ever managed to live prior to the discovery of America.

The subject of American cultivated plants is so vast that on this occasion I can merely give a brief abstract of some of my results. An extensive manuscript is almost ready and will be published at some later date. One of my results, I hope, may be of particular interest. It was hitherto unknown, at least to those who have widely written on the subject, when and how the potato reached North America. De Candolle merely dilates on speculations to the effect that some inhabitants of Virginia, perhaps English colonists, received tubers from Spanish or other travelers, traders or adventurers, during the ninety years which had elapsed since the discovery of America. Roze, Wittmack, Brushfield, Safford and others, to whom we owe monographs of the potato, are equally vague. It almost grieved me that we should be ignorant of the facts accompanying the introduction of the potato into our country, while almost all other nations have preserved a record of this event; hence I set out to delve in the early history of Virginia, but with no success. Finally, after several years' quest, I chanced to peruse the old "History of the Bermudas," and was at last rewarded by finding the desired information.

In 1613 the good ship *Elizabeth* brought potatoes from England to the Bermudas. The "Historye of the Bermudaes," ascribed to Captain John Smith (1580–1631), by others to Nathaniel Butler, governor of Bermuda from 1619 to 1622, reports this event as follows (p. 30): "In her wer first brought into thes partes certaine potatoe rootes sent from England, the which being planted and flourishinge very well, wer by negligence almost lost; at last, by a lucky hand, again revived from two cast awaye rootes; they have since encreased into infinite store, and serve at the present for a maine reliefe to the inhabitants." It was from the Bermudas that the potato was further transmitted to Virginia. On December 2, 1621, Captain Nathaniel Butler, governor of the Bermudas, sent from "St. Georges, in the Sommer Ilands," to the governor of Virginia (Francis Wyatt) two large cedar chests, "wherin were fitted all such kindes and sortes of the country plants and fruicts, as Virginia at that time and until then had not, as figgs, pomegranates, oranges, lemons, plantanes, sugar canes, potatoe, and cassada rootes, papes [papaya], red-pepper, the pritle peare [prickly pear], and the like" (*ibid.*, p. 277). In the following year, a Virginian "barcke took from the Bermudas twenty thousand waight of potatoes at the least" (*ibid.*, p. 285). All this is on record in the "History of the Bermudas." The fact that potatoes were actually planted in Virginia at the very moment of the first introduction is confirmed in letters sent from Virginia in

1621 and published by Purchas (vol. 19, p. 151): it is intimated there that "in December last they had planted and cultivated in Virginia potatoes and sundry other Indian fruits and plants not formerly seen in Virginia, which at the time of their said letters began to prosper very well."

The potato, accordingly, entered this country, not as surmised by de Candolle, through an alleged band of Spanish adventurers, but in a perfectly respectable manner—from England by way of Bermuda. It is a prank of fortune, of course, that the potato, originally a denizen of Chile and Peru, appears as a naturalized Englishman in the United States. This result is bound to modify to a large extent the entire early history of the potato as it has hitherto been conceived.

The potato had arrived in England about 1586 or a little later. For a long time the belief was entertained by botanists, even by H. Phillips and de Candolle, that the openauk, described among the wild roots of Virginia by Thomas Hariot in his "Brief and True Report of the New Found Land of Virginia" (London, 1588), was to represent our potato, that Hariot had brought his openauk-potato to England, and that from this source it was received by John Gerard, the first English botanist who raised the potato and described and figured it under the name "potato of Virginia." This speculation is erroneous: openauk is not the potato; Hariot does not claim that he ever took tubers of potatoes to England; indeed, he does not at all speak of potatoes, nor does Gerard mention Hariot's name or the openauk in connection with the newly introduced potato. Hariot described openauk as "a wild root found in moist and marsh grounds growing many together one by another in ropes." The potato certainly does not grow in swampy soil, and never occurred spontaneously in the United States or Mexico. Openauk, in fact, represents an entirely distinct plant, *Apios tuberosa*, popularly styled groundnut or Indian potato, a common article of food among the Indians. I am informed by Dr. Frank G. Speck, of the University of Pennsylvania, that in Penobscot there is a word *ponak* still applied to the groundnut. Be this as it may, from the data of the "History of the Bermudas" it is perfectly clear that "the potato was one of the plants which at that time and until then [that is, 1621] Virginia had not," so that it could not have been known to Hariot; and the fact remains that not a single account, report or letter from Virginia up to that date makes any mention of the potato, while after this date it is most frequently mentioned.

The question as to whom is due the honor of having first brought the potato to England is still deadlocked: the documents fail us. The principal testimony around which the history of the plant in England pivots is Gerard's who merely states, "It groweth naturally in America [this, in the language of the period, means South America], where it was first discovered, as reports Clusius, since which time I have received roots hereof from Virginia, otherwise called Norembega, which grow and prosper in my garden as in their own native country." Gerard's lengthy description and illustration of the potato has been harshly criticized, especially in England, but rather unjustly. In my forthcoming book, where the history of the potato in England is treated at great length, I have committed myself to a complete defense of Gerard's account, which is one of fundamental historical importance. Our imagination, of course, likes to attach the introduction of so useful a plant to the name of an individual, especially to one of historical fame. Sir Francis Drake and Sir Walter Raleigh have been considered in this

connection, and it is possible that one or the other may have had a share in the introduction, though documentary evidence is wanting; Raleigh is credited by popular tradition also with the introduction into Ireland.

The potato had to struggle for over a century in Europe before it met with general recognition; a rapid advance in its propagation was made in England only during the eighteenth century, and in France and Germany still later.

The civilized nations of Asia, while they adopted numerous plants from America, have not yet cast their vote in favor of the potato, but treat it rather indifferently or even disdainfully. This attitude is not the outcome of prejudice or an instance of inherited conservatism, as is often insinuated, but has its cause in the system of nutrition which prevails among those peoples and in which there is no place or vital necessity for potatoes. To be sure, the potato is grown almost everywhere in Asia, and is a favorite dish of all poor mountain-tribes, even in China; but nowhere has it deeply affected agricultural economy, nor does it offer a continuous stream of logical development. Not being national, its history is purely local and split into a series of incoherent efforts of a sporadic and isolated character.

On the other hand, the batata or sweet potato was never duly appreciated in Europe, but proved a prize-winner in the Far East. The admiration and enthusiasm, nay, ecstasy with which the batata was received in China, Luchu and Japan has no parallel in the annals of plant-introductions, and its history in those countries is a little romance hardly excelled by any other useful plant. As it has never been recorded from Chinese sources, a condensed digest of the story is herewith presented. In 1593, the province of Fu-kien in southern China, presumably owing to the ravages of a typhoon, was stricken by a famine. The governor of the province, Kin Hio-tseng, dispatched a commission to Luzon in the Philippines with instructions to search for food-plants which might relieve the pitiable plight of his people. Luzon then was thickly settled with Fukienese, who advised their countrymen to take the sweet potato along. The Chinese chronicle has it that the men beyond the sea, that is, the Spaniards, had strictly prohibited the exportation of the species, so that the Chinese were compelled to have recourse to subterfuge.[1] They wrapped cordage around the tubercular roots of batatas, till they had the appearance of ship-cables, and pretended to load their ships with ropes. Thus they safely reached Fu-kien in 1594 and taught their compatriots the cultivation of the novel plant, which was greeted with unbounded joy and which stemmed the tide of famine. In a short time special agricultural treatises and poetical compositions in honor of the batata were produced, and like a prairie-fire its cultivation spread over all parts of the country. The economic value and the highly nutritive properties of the newcomer were at once recognized. It is unmistakably described and figured and carefully distinguished from the many native species of Dioscorea, with which the batata is so frequently confounded: the Chinese still call it the "foreign Dioscorea" or the "Dioscorea of Governor Kin," at whose initiative it was introduced, and state advisedly that it was previously unknown in their country. In 1786 an im-

[1] I have not been able to trace a confirmation of this charge in contemporaneous Spanish sources; while the regulation somewhat savors of Spanish policy, no other example of such rigid exclusiveness is known to me, and I am rather disposed to suspect some exaggeration on the part of the Chinese, prompted by the desire to aggrandize the perilous nature of their venture.

perial order was issued to encourage the cultivation of the batata as a means of preventing famine.

From Fu-kien it was transplanted on the one hand to Formosa about fifteen years later, and on the other hand to the Luchu Islands as early as 1605. At that time the Luchans still formed a kingdom of their own, though recognizing the sovereignty of the Chinese emperor. Nugun, superintendent of the Chinese settlement in Napa, the chief town of the archipelago, presented a native village chief, Masatsune, with cuttings of the plant; he eagerly studied its mode of cultivation and promoted it in his country. In front of Nugun's tomb a memorial pillar has been erected, and he is canonized under the name Mmuushume, that is, Ancestor of the Tuber. On Luchu, where famines are frequently caused by typhoons, the plant has served as a real life-saving device; and as early as the seventeenth century it became thoroughly nationalized and next to rice the most important article of food; it is still the daily bread of the islanders.

A Japanese farmer, Maeda Riuemon, a native of the province of Satsuma, made the acquaintance of the batata while paying a visit to Luchu in the latter part of the seventeenth century. On his return home he introduced its cultivation into Satsuma, and from there it was disseminated over the northern provinces of Japan. Riuemon's tomb is known as Kara-imo-den ("Temple of the Sweet Potato"), where every spring and autumn the soul of this simple farmer receives offerings from his grateful countrymen. The earliest Japanese treatise on agriculture, the Nogyo-zensho, written by Miyazaki Yasusada in 1696, gives a very full account of the nature and method of cultivation of the batata, and was followed by two substantial monographs in 1716 and 1734. During four years of scarcity, in 1832, 1844, 1872 and 1896, the people of Japan were saved solely by sweet potatoes. The nomenclature follows suit with the historical facts: in Luchu it is known as the Chinese Dioscorea, in Satsuma as the Luchu Dioscorea, and in the rest of Japan as the Satsuma Dioscorea.

De Candolle and all previous investigators, who blindly followed him, were misled by a superficial statement of Bretschneider, who according to de Candolle "has proved that the species is for the first time described in a Chinese book of the second or third century of our era." This, however, is a fallacy and refers to a species of *Dioscorea*, not to *Convolvulus batatas*. This bulwark of an alleged Asiatic origin of the batata, heralded in numerous books, has now fallen. In de Candolle's justice it must be added, however, that he clearly visualized "powerful arguments in favor of an American origin, and that the latter appeared to him much stronger." But there was no prehistoric interchange of the plant between the New and Old Worlds or *vice versa*, as further intimated by him; the plant is decidedly one of American origin and migrated into the Old World only after the discovery. In fact, there is not a single document from which a pre-Columbian existence in Asia or Africa of the batata might be reasonably deduced. In India it makes its appearance toward the end of the sixteenth century as an introduction due to the Portuguese, and is known in all Dravidian languages under the Portuguese-American term *batata*. On the Moluccas it is called *castilian*, on Java and Bali *catela*, based on Castela-Castilian. It is maintained even by serious scholars that the batata has been a native of the South Sea Islands since ancient times. I fail to see any tangible evidence for this opinion. There is usually confusion with other species like *Ipomoeà mammosa*, a Convolvulus-like plant with an edible root, but of a distinct botanical character; this is a native

of the Moluccas, where it is also cultivated, and this is probably the batata mentioned by Pigafetta on the Moluccas in 1521. The early Spanish records, *e.g.*, those relating to the discovery of the Solomon Islands, mention taro and two kinds of yam, but not the batata, and the Spaniards coming from South America were surely familiar with this plant. Batatas, together with maize, squashes and *Phaseolus pallar*, were introduced from Peru into Tahiti by a Spanish expedition of 1772 under Don Domingo Boenechea, and a few years later Andia y Varela reports that the Tahitians grow two or three varieties of it. The Maori of New Zealand make a clear distinction between their native species and that subsequently introduced from America.

Finally, there is the testimony of the early discoverers of America and the contemporaneous European botanists, above all that of the great Clusius, who visited Spain in 1566, where he observed and described three varieties of batata. He states that it grows spontaneously in the New World, whence it was first brought over to Spain. "We sometimes have them fresh in Belgium," he adds, "but they will not germinate here, the country being too cold." Nicoloso Monardes, physician of Seville in 1572, likewise discusses the batata as a native of America and as widely cultivated and consumed in Spain in his time.

The history of the pineapple is of particular interest because it is so strikingly individualistic, quite in distinction from that of maize, which is so impersonal. A plant of such remarkable characteristics challenged the attention of all observant travelers. There is hardly any other plant the history of which is illuminated by such a flood of interesting documents. More than two hundred documents bearing on the pineapple have been brought together by me, and these have enabled me to trace the steps in its migration with a fair degree of accuracy.

The pineapple, the king of all fruits, as it has frequently been styled, belongs to the order Bromeliae, which consists of twenty-eight genera and 176 species—all natives of the American continent and insular groups, whence their distribution to many parts of the Old World has taken place. It is a particularly interesting point that in consequence of long-continued cultivation the highly cultivated varieties of *Ananassa sativa* have become seedless. This characteristic feature was emphasized as early as 1557 by André Thevet—a sure manifestation of the great antiquity of the cultivation in pre-Columbian America. Seeds are so scarce in the West Indies that there is seldom more than a single one found even in thirty or forty fruits. The plant is therefore usually propagated by means of crowns, slips, suckers and rattoons. The crown furnishes the most vigorous plants and yields the finest products. Plants are raised from seed only for breeding purposes, with a view to obtain novel varieties, but it requires from ten to twelve years to mature a plant from seed. The wild pineapple, on the contrary, is full of seeds, but small, seldom larger than an apple, stringy and rather acidulous in taste. It is only due to the process of cultivation that the fruit has acquired its large size and superior flavor. This was an accomplished fact when the first explorers of the Antilles and South America made its acquaintance.

The documents at our disposal warrant the conclusion that at the time of the conquest the pineapple as a thoroughly cultivated plant occupied the area of Brazil, Guiana, Colombia, parts of Central America and the West Indies. As early as 1519 it is mentioned in Brazil by Pigafetta as "a fruit resembling a pine-cone, extremely sweet and savory, in fact the finest fruit in existence."

André Thevet visited Brazil in 1555–56 and correctly figures and describes the fruit under the Tupi name *nana*. It was then medicinally employed by the natives, who also made a strong wine from it. Thevet's statement, that "the fruit bears no seed whatever and is hence planted by means of small slips, as fruits are grafted in our country," bears out the fact that the cultivation in Brazil must have been many, many centuries old. Jean de Lery, the Huguenot clergyman, who came to Brazil in 1557, is the first to employ the word *ananas* as being derived from the language of "the Savages." Christoval de Acuña, in 1639, found the Indians of the Amazon Valley using pineapples as food. In his "Discoverie of Guiana" (London, 1596), Sir Walter Raleigh speaks of "great abundance of pinas, the princesse of fruits, that grow under the sun, especially those of Guiana."

Although not mentioned by Columbus himself, the pineapple is placed on record by his contemporaries and epigones, who made use of his and his companions' diaries, letters and reports; first of all, by Peter Martyr d'Anghera, who offers three notices of the curious plant in the second and third decades of his *De Orbe Novo*, first published in 1516; this is the earliest record of the pineapple in existence. Martyr describes it as an herb resembling a pine-nut, artichoke or acanthus, raised in the gardens of the West-Indian islanders, worthy of a king's table; King Ferdinand of Spain had eaten a fruit shipped from Darien and awarded to it the highest praise. A lengthy, though somewhat verbose and cumbersome description, is inserted in Oviedo's "Historia general y natural de las Indias" (1535). There are numerous old accounts for Cuba, Porto Rico, and other islands, where many varieties were raised at an early date.

In ancient Peru, the pineapple was unknown: it is conspicuously absent in Peruvian archeology, not being found in any graves, nor is it represented on pottery vessels. Joseph Acosta, in his "Historia natural y moral de las Indias," states expressly, "It does not grow in Peru, but is carried there from the Andes, and this fruit is neither good nor ripe." Cieza de Leon mentions it only as growing in Cali, a Spanish settlement of Peru, together with a series of plants introduced from Spain and the West Indies. Finally, there is a formal, though somewhat belated, testimony to the effect that the plant was introduced into Peru from Brazil. G. Piso, in 1658, asserts that, according to a statement of trustworthy old natives of Brazil, the fruit was transmitted from Brazil to Peru. The oral testimony of old men, especially with reference to an event that dates back at least a century, is somewhat subject to suspicion, but there is no doubt of the fact that the pineapple was not imported into Peru until after the conquest. It is not amiss to emphasize this point, in view of the information given in the "Treasury of Botany" that the pineapple first became known to Europeans in Peru, where it is called *nanas;* and most of our dictionaries, even the Oxford New English Dictionary, wrongly define *ananas* as a Peruvian word. In fact, this word does not exist in any Peruvian language, or in Spanish. From the reports of Thevet and de Lery it is perfectly obvious that the word originated in Brazil, where it still occurs in Tupi. The Brazil Portuguese term has conquered all vernaculars of Africa, India, Malaysia, and all European languages, with the exception of modern English, pineapple being modeled after Spanish *piña,* while in seventeenth and eighteenth century English *ananas* was still frequent.

The antiquity of the fruit in Mexico and among the Maya does not seem to be well authenticated: Sahagun apparently does not mention it. Geronimo Benzoni, from Milan, who sojourned in Mexico

from 1541 to 1555, gives a brief, though colorless, description of the plant in his "History of the New World" of 1578, without special reference to Mexico. Francisco Hernandez, in his "Rerum Medicarum Hispaniae Thesaurus" (Rome, 1651), writes that he found the pineapple (termed by him *Pinea indica*) in the warm regions of Mexico and Haiti, and furnishes a drawing of it under the Aztec name *matzatli*. This comparatively late evidence, however, does not suffice to regard the pineapple of Mexico as pre-Columbian.

According to W. Popenoe, the pineapple was doubtless cultivated by the ancient Maya, and is still grown in several gardens near Copan. This conclusion, however, is inferred from present-day conditions; it is retrospective and remains to be substantiated by more solid data.

In the West Indies the pineapple occurs solely in the state of cultivation or occasionally as a fugitive, while without any doubt this cultivation is of ancient date and was an accomplished fact at the time of the Spanish conquest. The wild congeners of the plant and many other representatives of the genus, however, are to be found in Brazil and Guiana. It is therefore reasonable to regard Brazil as the mother-country of pineapple cultivation: Brazil was one of the great centers of aboriginal agriculture, from which also emanated the sweet potato, the cassava, the peanut, Capsicum, several species of beans, and others.

The pineapple was introduced to Bermuda from the West Indies under Captain Tucker (1616–19), third governor of the islands.

An early attempt to acclimatize the fruit in Virginia proved a failure. W. Strachey[2] reports in 1614, "The rootes of the delicious Indian pina, sett in a sandy place, thrived, and contynued life, without respect had of yt, untill the cold wynter and the weedes choaked yt; yet is this fruict said to be daintye, nice, and of that nature, that noe art or industry hath be found out hitherto that could preserve yt in any clymate but in the West Indie Islands only." In December, 1621, pines were shipped to Virginia from Bermuda, together with potatoes, sugar-canes and plantains, and began to prosper well, as we learn from a contemporaneous document published by Purchas. I have not yet been able to trace any subsequent documents, and do not know what the outcome of these initial experiments was. Pineapple cultivation in the south of Florida is a recent event, not earlier than 1886.

In English literature the pineapple is first mentioned in 1568 in the "New Found Worlde or Antarctike," which is a translation of André Thevet's "Singularitez de la France antarctique autrement nommee Amerique"; for the second time in 1580 in John Frampton's "Joyfull Newes out of the New Found World," which is based on the Spanish work of Nicoloso Monardes. John Gerard, in his famous "Herball" of 1597, is not yet familiar with the plant; but in the second edition of 1633, prepared by Thomas Johnson, it is described and accompanied by a woodcut of the fruit. John Parkinson, in his "Theatrum Botanicum," published in 1640, is more copious in his description, more accurate in his illustration and gives more information concerning its history. He states that the Anana or West-Indian delicious pine was first brought from Santa Cruz in Brazil, where it grows wild, and was thence introduced to the East and West Indies, being not a native of either; in Brazil, it is called by the natives *nana* and *anana*, but by the Spaniards and Portuguese *piñas*.

In 1657 Oliver Cromwell received four pineapples brought back by an embassy

[2] "Historie of Travaile into Virginia," p. 81. Hakluyt Society.

returning from China. This event is alluded to by John Evelyn in his "Diary," where under date of August 9, 1661, he writes, "I first saw the famous Queen pine brought from Barbadoes and presented to his Majesty Charles II; but the first that were ever seen in England were those sent to Cromwell four years since."

Under date of August 19, 1668, we read the following in Evelyn's "Diary":

I saw the magnificent entry of the French Ambassador Colbert, received in the Banquetting-house. . . . . Standing by his Majesty at dinner in the presence, there was of that rare fruit called the King-pine, growing in Barbadoes and the West Indies; the first of them I had ever seen. His Majesty, having cut it up, was pleased to give me a piece off his own plate to taste of; but, in my opinion, it falls short of those ravishing varieties of deliciousness described in Captain Ligon's History, and others; but possibly it might, or certainly was, much impaired in coming so far; it has yet a grateful acidity, but tastes more like the quince and melon than of any other fruit he mentions.

It would follow from this notice that the pineapples of King Charles were imported from America.

Lady Mary Wortley Montagu (1689–1762) writes in one of her letters, dated Blankenburg, December 17, 1716:

I was particularly surprised at the vast number of orange-trees, much larger than any I have ever seen in England, though this climate is certainly colder. But I had more reason to wonder that night at the king's table (in Hanover). There was brought to him from a gentleman of this country, two large baskets full of ripe oranges and lemons of different sorts, many of which were quite new to me; and, what I thought worth all the rest, two ripe ananas, which, to my taste, are a fruit perfectly delicious. You know they are naturally the growth of Brazil, and I could not imagine how they could come there but by enchantment. Upon enquiry, I learnt that they have brought their stoves to such perfection, they lengthen the summer as long as they please, giving to every plant the degree of heat it would receive from the sun in its native soil. The effect is very near the same; I am surprised we do not practise in England so useful an invention.

As to the source from which the two pineapples served at the electoral table of Hanover had come, we receive a bit of information from the philosopher Leibnitz, who wrote about 1714 as follows:

All the travelers in the world would not have given us by their relations what we are indebted for to a gentleman of this country who cultivates with success the ananas, three leagues from Hanover, almost on the banks of the Weser, and who has found out the method of multiplying them, so that we may perhaps have them one day as plentiful, of our own growth, as the oranges of Portugal, though there will, in all appearance, be some deficiency in the taste.

This remark refers to Otto von Münchhausen, who in his gardens not far from Hameln erected large buildings for the express purpose of raising pineapples, in the beginning of the eighteenth century.

Lady Montagu, however, was not quite correct in her surmise that so useful an invention was not practiced in England. In fact, pineapples were produced in English hothouses several years before they were established in Germany. This was first accomplished in the gardens of Amsterdam by means of plants introduced from Java, Surinam and Curaçao; and from Holland the art spread to England, France and Germany. During the eighteenth century, the culture of pineapples in hothouses was understood by almost every gardener in England. There are a number of very interesting treatises on the subject written by practical English gardeners, such as Speechly, Abercrombie and Baldwin, with full details bearing on the numerous varieties then produced. The Fitzwilliam Museum at Cambridge preserves a landscape by Netcher in which a pineapple is introduced. It is there stated to have been the first that ever fruited in England, and that it was produced in the gardens of Sir Matthews Decker, at Richmond in Surrey (in 1712).

Soon after the discovery of St. Helena in 1502 the Portuguese transplanted there the pineapple, together with many other fruits, vegetables, cereals and cattle, all of which flourished abundantly on the island after a short period. There is no doubt that the Portuguese were active in diffusing the plant along the west and east coasts of Africa and on Madagascar at an early date; through their agency the term *ananaz, nanasi* or *manasi* penetrated into the native languages of Africa. In the account of the Dutch expedition to Guinea in 1602, a lengthy description of the fruit and its usefulness is given; its cultivation on the part of the inhabitants of Guinea then was an accomplished fact. M. Hemmersam, in the account of his voyage to the coast of Guinea (1639–45), writes that "the Moors consume quantities of ananas, as they call this fruit, which is like an artichoke; they also cook it, mixing it with palm-oil which they use for all their food in the place of fat; it belongs to the best fruit of this country and makes an excellent dish when sliced and soaked in Spanish wine, but too much of it entails malady." Etienne de Flacourt, who was governor of Fort-Dauphin on Madagascar from 1648 to 1655, has left interesting observations on pineapple culture in the island, which are inserted in his "Histoire de la grande isle Madagascar" (1661). At the same time, the plant was cultivated on Réunion (Bourbon) and Mauritius, as we learn from Du Quesne and François Leguat. The Mauritius variety is of superior quality, and was also introduced into India. About 1660 the Dutch planted pineapples at the Cape of Good Hope. These had been brought over from Java by Georg Meister, a professional gardener, who himself tells this story in his very interesting diary.

About 1550 or shortly afterwards, the pineapple was introduced into southern India by Garcia da Orta, a Portuguese physician, author of the famous "Coloquios dos simples e drogas da India" (Goa, 1563), who mentions it as an introduction from Brazil; but more than that—it is unmistakably described in the Ain-i Akbari ("History of the Emperor Akbar"), written in 1597 by Abul Fazl Allami. The Emperor Jahangir tells in his "Memoirs," under the year 1616, how a large tray of fruit was brought before him, among these pineapples from the seaports of the Frangi; that is, Franks, Portuguese. "Some plants of this fruit," the emperor goes on to say, "were placed in my private gardens at Agra, and after some time they produced several thousands of that fruit."

Huygen van Linschoten, in 1596, describes ananas as one of the best fruits and of best taste in all India, and adds, "But it is not a proper fruit of India itself, but a strange fruit, for it was first brought by the Portingalles out of Brasille, so that at the first it was sold for a noveltie, at a pardão apiece, and sometimes more, but now there are so many grown in the country that they are very good cheap." Nearly all travelers to India in the seventeenth century describe the fruit and eulogize it. François Pyrard, whose peregrinations in the East extended from 1601 to 1611, even enumerates it among the productions of Nepal. It likewise spread at the same time to Bengal, where Nicolao Manucci reported a more extensive cultivation than anywhere else in India, and where the fruit was also preserved; in the latter part of the seventeenth century it advanced to Assam, Burma and Siam. In Assam, more particularly the Khasia hills, as well as in the forests of Ceylon, it has escaped from cultivation, and has thus become seemingly spontaneous, but even these semi-wild plants are still designated by the natives with the Brazil-Portuguese terms *ananas, anasi,*

etc., which, with slight modifications, are echoed in all languages of India and Malaysia, with the sole exception of Tagalog, which has adopted Spanish *piña*.

Before the close of the sixteenth century, the pineapple had reached Malaka and Java. The Malaka product soon achieved a reputation all over the East. In 1637 Peter Mundy, a prominent English traveler, found pineapples planted, while passing through the strait of Singapore, and even on outlying islands as Pulo Tinggi off the east coast of Johor. Engelbert Kaempfer encountered them in 1690 on his voyage from Batavia to Siam on the island Puli Tumon near the east coast of Malaka.

In China we meet the fruit from the beginning of the seventeenth century. It is not mentioned in Chinese records at an earlier date. It is not correct, however, as has been asserted, that the plant reached China through the Philippines. Chinese authors are reticent as to this point, and it is more probable that the Portuguese brought it from Malaka to Macao, where it is still cultivated and whence it was disseminated into the province of Kwang-tung and the island of Hai-nan. From Hai-nan it was transmitted to Fu-kien and Formosa, where it was noticed as early as 1650 by John Struys. On the other hand, it also appears to have entered Yün-nan Province from Burma. Chinese names for it like "foreign jackfruit," "royal pear" or "phoenix pear" are likewise an index of a recent introduction. Pineapple cultivation and cannery have reached a great economic importance in China and Indo-China, the fruit being consumed by all classes of people in enormous quantity, and the fibers of the leaf being utilized for textiles. As to Japan, the fruit was first introduced into Nagasaki by the Hollanders as late as 1845.

WHY WE HAVE EMOTIONS

By Professor CHRISTIAN A. RUCKMICK

UNIVERSITY OF IOWA

THE explanation of the emotional life of man broadly implied in the title may appear to be somewhat ambitious. Like many other explanations all that we can hope to do is to scratch the surface or at best perhaps to dig a short distance down. If in this attempt we strike basic rock we are fortunate, but even then the process of sinking shafts through the rock is only begun. In answer to the general question, therefore, all that we can do is to trace human emotions to more fundamental principles. Having worked for many years in this field, the writer has given some serious thought to the matter of explanation and believes that he has at least a tentative answer to the question raised in the title.

The problem of emotion was one of the earliest to arise in the inquiring mind of man. It was not as insistent in its demands as was the question of reason and intellect, nor did it for so long a time occupy the high seat of honor. In almost every cosmology, however, it finds a place, and nearly every religion deals with it in one form or another. Confucianism centers its influence around *shu*, the sign of the heart, which is expressed in the Golden Rule; Brahmanism makes blissfulness (*ananda*), together with reflection and being, one of the three aspects in the general formula for the godhead; the idea of God the Compassioner, or Rahmān, is deeply imbedded in the Koran, side by side with the fearful torments of a wrathful deity; reverence for ancestors forms one of the cornerstones in the doctrines of Shintoism; and in our New Testament the message that God is love replaces the more austere dogma that Jehovah is exacting and revengeful, as he is described in many places in the Old Testament.

When we scan the horizon at the dawn of occidental science, again we find emotion given a place at least in the twilight. The Greeks hardly ever failed to emphasize the importance of this aspect of our lives, and the great Homeric epics are full of emotions of the gods and the heroes. The "Iliad" begins with the dramatic sentence, "Sing, O Goddess, of the consuming wrath of Achilles, son of Peleus, that has thrust countless woes upon the Greeks." Soon we find the magnificent war-lord Agamemnon so perturbed that "his mighty midriff, black on both sides, heaved with anger, and his two eyes seemed to shine forth like fire." In another connection Apollo's "heart burst with anger." The early philosophers, too, gave the emotions a significant position in their systems of first causes, and Anaximander, six centuries before Christ, makes love one of the indestructible principles of the cosmos, while later Empedocles reduces the universe to earth, air, fire and water, which are attracted to each other by love and repelled by strife.[1]

After this early Greek period emotion no longer attracted the attention of thoughtful writers, who were mainly concerned with questions related to in-

[1] From this it is a far cry to the analysis recently made by Millikan, in an address before the Society of Chemical Industry, when he stated that in addition to the positive and negative electrons, the fundamental elements in the world are helium, oxygen, silicon and iron. But it is significant to note that in this partnership of universal causes iron is the only stranger, while love and strife have turned into positively and negatively charged electrons!

telligence, reason and the will. For Plato, love comprised both the sensuous impulses on the one hand and the soul's highest yearning for eternal beauty, goodness, truth and immortality, on the other. Aristotle in his psychology delicately poised the emotional life of man between reason and desire. A little later Epicureanism built up a philosophy of pleasure, but noted nevertheless that the pleasures of the mind were more desirable than mere bodily pleasure and warned its followers that many pleasures were followed by pain. By this time, however, the question took on moral aspects, and cosmological analysis gave way to ethical culture. When Neo-Platonism and Christianity began to show their influences the emotional life of man was for the most part either discarded as unworthy of discussion or disregarded altogether.

Some philosophers considered this aspect of the human mind only to dismiss it with scant treatment. Descartes remarked that it represented merely the agitation of the animal spirits in the pineal gland; Spinoza called it a confused idea due to fluctuations in the vital stream; and Herbart regarded it for a moment as the discarded waste in the up-building of the mind.

The very fact that these seekers after truth concentrated their attention on that aspect of the mental life which is embodied in the concept of intellect, led them to overlook certain rather startling events which became more and more impressive in connection with the emotional experiences of man. From the philosophical point of view, of course, it was necessary to discover what were the channels through which knowledge came and what were the usual errors in the reasoning process. But insistent problems dealing with other aspects of the mental life clamored for solution from the minds of thinking men. It was soon discovered that human beings did not live by intellect alone. Bitter wars were fought because men were stirred up and fervently aroused. Great issues were often not solved by pure reason or near-reason, but by emotion and sentiment. Then there were human derelicts around: men and women of well-developed wits and mature intellect, but with malformed emotions. They were like high-powered explosive mines swept from their moorings and adrift in the lanes of human navigation. There seemed, moreover, to be massive human icebergs afloat, huge fragments of congealed mind without a spark of emotion left in their lives. Dealing their massive blows with six sevenths of their bulk below the water line, in darkness and in fog, they menaced the morals of mankind. The life stream that was once a limpid and refreshing mountain brook became now the frigid fist of death. So in all time, not only in our time, emotionless fiends as well as frenzied fiends have claimed their victims. This human flotsam and jetsam soon came into the focus of scientific scrutiny and new questions were raised in the thinking world.

The task became complicated. From many new angles the questions concerning the emotions pressed for answer. Patients under care and treatment had developed curious emotional disorders. Manic-depressive psychoses, hysteria and schizophrenia were being noted and described. The testing of intelligence also raised new issues with respect to persistence of effort, interest and honesty. Every one wished for facts that were not yet at hand and are indeed still wanting. Partly because of this prolonged neglect of an integral portion of our mental lives we are now in dire need of reliable information in regard to the emotions of man. But the quest is on.

The direct drive in this direction can be dated from the middle of the last century. Darwin had brought forth his

"Origin of Species" in 1859. In 1873 he had already applied his three great principles of emotional interpretation to human as well as to animal expression of emotion in his monumental work, "The Expression of the Emotions in Man and Animals." These three principles were: (1) serviceable associated habits; (2) antithetic attitudes, and (3) neuro-muscular response. The first principle stated that voluntary movements made through many generations and expressing a useful biological purpose tend to survive under similar conditions, sometimes in a weakened form, even when no longer useful. For example, in the disdainful grin of superiority, the canine teeth are bared even though we no longer put them to use to prove that superiority. The second principle states that when an organism has made movements that suit a certain situation, these movements are frequently followed by expressions which are exactly opposite to the first group. For example, when an organism sets itself for an attack and finds that the object of attack is really a friendly being, just the opposite movements will result, *i.e.*, those of almost excessive crouching in the attitude of servility. The third principle refers to the apparently useless movements which are due to direct nervous excitation, like the trembling which accompanies fear and the condition of cataplexy which results in certain situations of fright and awe. Several outstanding contributions to the subject of emotional expression had already been made and are noted by Darwin in his introduction.[2]

But from the psychological point of view the reduction of the emotional life simply to movements and changes of or within the body affords an insufficient explanation. The study of the bodily accompaniments of emotion is an exceedingly fruitful one—one that has developed indeed an entirely new series of techniques and one that has far extended our physiological and biological knowledge. Behind it, however, lies the more intricate problem of the relation between mind and body, than which there is probably no more perplexing question, unless it be the more fundamental metaphysical issue of the ultimate reality of the universe itself. Since the relation between mind and body has already received thorough-going consideration in scores of articles and dozens of volumes, a paper of this length can give it only relatively scant notice.

In order to deal with the question satisfactorily we shall have to raise and answer the logically prior query, what is the nature of emotion? Experimentally, of course, the problems of description and explanation may proceed side by side and thus become mutually helpful. Similar situations have arisen in sciences other than psychology. For example, why we have an electrical flow of energy, may be answered after a fashion before we have anything like a final reply to the question, what is electricity? We can discuss the question, why we have brains, without having settled the more fundamental question, what really is the brain? For a moment let us digress therefore to face the issue of the nature of emotion.

The conception as well as the terminology is becoming more stabilized. It is clear that originally the term and its corresponding conception had a strong physical, sometimes even a geographical and meteorological implication. Indeed, the first appearance of the term indicated a migration of peoples. In 1579 Fenton so used the term: "There were

[2] Among them are Sir Charles Bell's "Anatomy and Philosophy of Expression" in 1806; Moreau's edition of Lavater, "L'Art de Connaître des Hommes" in 1807; "The Physiology of Mechanism of Blushing" in 1839 by Dr. Burgess; Dr. Piderit's "Grundzüge der Mimik und Physiognomie," 1858, in which appears his "Geometry of Expression"; and Gratiolet's "Concerning the Physiognomy and Movements of Expression," 1865.

. . . great stirres and emocions in Lombardye." In 1773 we read of an "emotion of the center of gravity," and in 1755 of an "emotion of thunder in the air." Addison in his *Tatler* (1709), described a political agitation under the title, "Accounts of Publick Emotions, Occasion'd by the Want of Corn." Gradually this notion of agitation and commotion is transferred to the human and animal body, and we are not sure whether the experience of emotion or the bodily movements or both are referred to. For instance, in John Locke (1693) we read:

> I think nothing need to be said to encourage it [bathing in cold water] provided that this one caution be used, that he never go into the water when exercise has at all warm'd him or left any emotion in his blood or pulse.

Many of us recall a similar situation in Hawthorne's "House of Seven Gables" (1851), where he writes, "Mellow melancholy, yet not mournful, the tones seem to gush up out of the deep well of Hepzibah's heart, all steeped in its profoundest emotion." In French the term is the equivalent of the English, while in German the more technical term is *Affekt,* but one of the more general terms is *Gemütsbewegung,* which means a movement referred to the life of feeling and will.

In fine, it becomes clear that the background of emotion is distinctly one of movement or commotion and that there has always been a strong bodily implication. Even the Greeks, as we noted above, were prone to locate the emotional life, if not indeed the whole mental life, in some physiological organ of the body.[8]

[8] Dr. A. Sophie Rogers in an unpublished manuscript made a complete study of the places where the mind was located in many writers among the earlier Greeks and Romans. The organs affected by emotions in one form or another included: body in general, brain, breast, diaphragm, gall bladder, heart, intestines, jaws, kidneys, liver, lungs, limbs, medulla, spleen, stomach, throat, viscera.

Aside from the gross psychophysical error which still persists when uninformed individuals place the non-physical mind into a physical brain, it is to our point here to notice that a reference to the body existed among the early thinkers.

Before we go further, however, into this matter of the interrelation of mind and body, we shall have to face for a moment and in a preliminary fashion the question of the nature of emotion itself. From the large number of descriptions of emotions found in the literature we can gather together at least five specific factors which are usually definitely stressed.

First, with few exceptions, an emotion is recognized as a complex and not a simple experience—one, therefore, which could not be found in comparatively simple organisms. Our comparative psychology teaches us that not only the biological life but also the mental life of these organisms is devoid of the more complex processes. But emotions as commonly described are extremely intricate and all-absorbing in the sense that all mental processes are intimately and most completely dissolved in the entire mass or pattern which we call emotion. At the moment of seizure there is nothing left in the total experience of the individual that is left out of emotion. This is one reason why it has been difficult to analyze it by direct observation or without the expertness that comes from practice.

Secondly, the emotional experience as we define it passes with a high degree of vividness and clearness. It is a very lively affair and does not go off in a half-cocked condition. Mind is all there—no one ever has had an emotion while he was half asleep or half awake. Even in sleeping the limited number of emotions that occur are very vivid experiences and often result in awakening the individual.

Thirdly, the entire process or experience follows a temporal pattern and an order of bodily responses which are largely inherited and which can incidentally be traced on that account to organisms biologically related to mankind. The march of mental events, in fact, the entire mental picture of emotion in general and of every kind of emotion in particular is so much a matter of our common inheritance that we can find more resemblances than differences from individual to individual. The same can be said about bodily responses. Here, too, there are individual idiosyncrasies. In anger, for instance, one person may flush in the face, another behind the ears, a third in the back of the neck, while a fourth may grow pale in one or more of these regions. There are similar differences in the type and degree of other bodily responses, including, as we have discovered, the character and amount of electrical resistance of the body. One must not omit, of course, the changes due to acquired control and inhibition of voluntary muscle systems, including some so-called involuntary ones. The writer has found, for example, two students of his, both girls, who could voluntarily open and close the pupils of the eyes. And the medical journals have reported at least fifteen instances of the voluntary control of the heart beat. All these bodily responses have been most extensively studied in the literature.[4]

Fourthly, emotion is unique in that it is founded upon a distinctive attribute of the mental life known as feeling or affection. Some attempts have been made to reduce these affective qualities, now predominantly known as pleasantness or unpleasantness, to some such sensory level as pain and tickle, or as dull and bright pressure.[5] But on the whole these positions have not been widely accepted. Several discussions, like those of Dunlap, Royce and Wundt, have aimed at a multiplication of these qualities. But their findings have not been corroborated by further experimental work.[6] This unique aspect presents its own problems and difficulties. Bentley believes feelings to be like a haze or mist and refers to them as affective tone; Calkins calls them "attributive elements of consciousness"; Pillsbury calls them subjective in reference; Seashore works feeling into a tridimensional diagram as relief or depth, and Titchener remarks the absence of the attribute of clearness or vividness.[7]

Fifthly and finally, emotion is described as referring to or involving the cognitive function of perception or idea, presentation or representation. Most

[4] H. F. West and W. E. Savage, "Voluntary Acceleration of Heart Beat," *Arch. of Intern. Med.*, 22: 290–5, 1918.

[5] The outstanding instances in the literature are principally found in the following writings: Carl Stumpf, "Ueber den Begriff der Gemüthsbewegung," *Zeits. f. Psychol.*, 21: 47 ff., 1899, who in the main reduces the feelings to such cutaneous patterns as tickle and itch; W. James, "Principles of Psychology," 1890, Vol. II, Chap, 25, where, in his famous theory of emotions, he reduced the total affective pattern to visceral sensations; see also his article, "What is Emotion? *Mind*," *O. S.*, 9, 189, 1884; this extreme position was somewhat modified in his later discussion, "The Physical Basis of Emotion," *Psychol. Rev.* 1: 516–29, 1894; J. P. Nafe, "An Experimental Study of the Affective Qualities," *Amer. J. of Psychol.*, 35: 507–44, 1924. Another possibility is contained in the statement of K. Dunlap, "Elements of Scientific Psychology," p. 317, 1922, "The most plausible processes as a basis for these feelings have been claimed to be the tumescence and detumescence of the erectile parts of the generative organs, but this assumption is merely tentative, and hardly yet sufficiently indicated as a working hypothesis."

[6] K. Dunlap, *op. cit.*, p. 315 ff.; J. Royce, "Outlines of Psychology," 1903, p. 176 ff.; W. Wundt, "Grundzüge der physiologischen Psychologie," 6th edition, 1911, Vol. 3, p. 199 ff.

[7] M. Bentley, "Field of Psychology," 1924, 84. M. W. Calkins, "First Book in Psychology," 4th Rev. Ed., 184. W. B. Pillsbury, "The Fundamentals of Psychology," 1916, 448 ff. C. E. Seashore, "Introduction to Psychology," 1924, 304 ff. E. B. Titchener, "A Beginner's Psychology," 1915, 79 f.

writers point out that when we experience an emotion, we become aware at the same time of a specific object, event or situation in the environment which may be or may not be physically present but which elicits the emotion and toward which the specific emotion is directed. In other words, objectless emotions have been found with only extreme rarity. Some that have seemed to be objectless of course contain ideated objects not physically present. As James further points out, if no external causes are present, the causes, especially in pathological persons, are bodily causes that thus become objectified. Anger, fear, love, and all the rest, are directed toward objects of which the experiencing person is aware but which may or may not be physically present. Sometimes if no object readily presents itself for such emotional outlet, it is mentally created. A writer on adolescence remarks that many young people who write diaries personify the diary because no one else is considered worthy of these confidential statements and the attendant emotions. Children sometimes create fictitious companions. Some one told the writer the other day of an interesting example in which a boy developed a series of adventures and a life history for an imaginary hero whom he called "Grease-Fight," concerning whom a large number of emotional situations were evolved.

Now that we have the picture of emotion sketched in sufficiently for the purpose of this discussion, we may answer serially the question raised in the title by referring to each one of the several features outlined. Some of these items have mutual interrelations and can therefore be gathered in groups.

The problem of the complexity of the emotion is one which has not been fairly faced by way of explanation. Krueger[8] has just recently suggested one explanation for it, and others have barely touched upon it. Basically, it is a genetic question, and the answer to it forms the main contention of the paper. Much has been written about the theory of emergent evolution for mind in general. Notably Lloyd Morgan and Patrick have shown how mind may be considered as one of the latest appearances in the upward urge of evolution. In the same way each particular phase of mind can be said to emerge as a form or pattern when mind itself has arisen as one of the emergent aspects of natural life. Emotion, then, may well be one of these patterns or configurations that have appeared from time to time as mind became more and more complexly developed. It must not be surmised at this point that emotion emerged full-fledged out of the mental life as Athena was said to have been born in complete armor out of the head of Zeus. It is an average concept with many gradations and several approximations. Any gradual development offers the same difficulty. One might well compare the homely illustration of a rose passing from bud to flower. Emotion, moreover, as far as man is concerned, is itself only an intermediate step in the development of the mental life from its feeling aspect. We have in man what appear to be still more highly developed feelings in the so-called tender emotions or sentiments.

It matters little what was the original process out of which emotion has developed or what was the precise order in the genetic procession. Titchener claims that sensation and affection are both derived "from a common mental ancestor."[9] In his view, sensations were gradually more highly developed while the growth of the affective process was arrested. Hence its scarcity of qualitative and quantitative attributes and its lack of end-organs. He hazards a guess that the free afferent nerve-endings serve as its peripheral organs. Ribot, on the

[8] F. Krueger, "Komplexqualitäten, Gestalten und Gefühle," 1926.

[9] E. B. Titchener, "Textbook of Psychology," 1919, p. 260.

other hand, points to the purely affective life of the very young child, but he does not deny that even in the intrauterine period there may be "internal sensations" or cœnaesthesia,[10] the technical name for sensations from within the body, or what Warren calls "systemic sensations." In other words, Ribot believes that we can have a mind that is made up entirely out of simple feelings.

Be that as it may, in children and probably in the race, emotions are later developments. Preyer found fear, which was the first emotion to appear, present from the second day on; Perez from two months on, and Darwin at four months and after. Watson finds the fear reaction present at birth, even in decerebrate infants. But since all these studies describe only the responses and can not describe the accompanying experiences, not much can be gained for our present purpose from such accounts. Almost all writers agree, however, that emotions are not experienced in comparatively simple organisms, although in these there may be present some form of sensory experience with or without some phase of feeling. Only when the perception or ideation of a total situation has been developed and not merely the bare sensible quality that follows upon a stimulus can anything like an emotion arise. And just as the instinct is more than a congeries of reflex reactions, each one responsive to its peculiar stimulus, so the emotion is more than a summation of feelings. This total perception is apparently present in forms as low in the scale of evolution as wasps and spiders, but is not present in protozoa and many of the simpler metazoa, where a fusion of several stimuli into one special form is not yet possible. Volkelt maintains that a fly out of the web is not cognized as the same thing by the spider as a fly in the web. Experiments have shown that bees and wasps will not enter their hives if a slight change in the environment has taken place. Washburn makes a further point in this connection by showing that perception is itself conditioned in animals like raccoons, elephants and monkeys by the fact that for the first time objects can be voluntarily moved in their surroundings. These perceptions are therefore more like those of man. Man has emotions, then, because he cognizes his external world in its various relations as well as in terms of objects and events. Out of the two hundred or more emotions analyzed in our laboratory, fully three fourths show the significance of ideational factors which could not be present in lower animal forms. Our emotional reaction to the dead human body, even when much disfigured, is greatly modified by our theory of the relation between body and personality. Before we learn that the most nerve-racking groans may be emitted by a totally anesthetized subject under a major operation, our emotional responses are entirely dependent upon the perception of these groans as a index to human suffering. But even here, as in James's illustration of his own childhood experience with the bucket of blood, the inherited part of the total pattern is sometimes hard to subdue by reason or by learning. All that we now contend is that the emotion, like many of our other human experiences, may be much modified in terms of the actual conditions cognized.

Our experimental results in the laboratory again clearly show that we are lucky if the same environmental situation brings forth the same emotion, or any emotion at all, in every individual tested. In one outstanding case, a pistol presented suddenly to the head in an otherwise peaceful situation did not elicit the usual emotion of startle or fear in a female observer, but only the

[10] T. Ribot, "The Psychology of Emotions," 1897, p. 8.

comment, "What a rusty old pistol that is." In the northern timber lands she had frequently slept with a firearm under her pillow while on cross-country hikes, and her somewhat peculiar experience had modified the usual emotion almost to the vanishing point. Only under rare circumstances and with much forethought can we set up experimental conditions that will arouse approximately the same emotion in a score or more of observers.

The fact that the development of the mental life must be ripe for the proper emotional experience was definitely shown in experiments carried out by G. S. Gates with the author's photographs of emotional expression. Expressions of pleasure were recognized by the majority of the kindergarten group, pain by a majority of the first grade, anger by the third grade, fear in the fourth grade, surprise and wonder in the sixth grade, but scorn was recognized by only 43 per cent. of the fifth grade. Apparently "scorn" is one of the emotions that require a background in actual experience. The growth of emotional reactions as well as the wide individual differences have been noted in our Child Welfare Station by Marston who found an increasing tendency in children to inhibit outward manifestations of emotion as they grow older.

We intimated above that mental development on the side of feelings does not stop with emotion. Already in classifying the emotions distinctions have been drawn within this category between the primitive emotions and the subtler or higher emotions. In man, so far as we can discover, we have the first appearance of that stage in the emergent evolution of the complex mental process known as sentiment. Here the hereditary factor is not nearly so strong as it is in emotion, and the idea has largely replaced the percept as the basic mental process or function. We often actually see and hear objects which arouse sentiments, but the sentiment itself is conditioned primarily by the ideational content and the abstract meaning which the percept conveys. Not the national flag as a visual perception or a funeral march as a auditory process *per se* but the abstracted meaning that lies behind these experiences stirs up our sentiments. This point is also raised and developed in several recent books on wit and humor. The type of joke that a person will enjoy might well be used as a test of his mental culture. Hence the low rating which puns usually receive!

In fine, then, our point is that we have emotions because, first of all, the mental life contains the feeling component which has grown up side by side with our cognitions, but in not nearly so detailed a manner as they have. We must not forget that the agreeableness and disagreeableness of experiences have long been with us in the steady development of the mind. The next step to a pleasant or unpleasant sensory experience was the emotional pattern with its inherent cognitive processes and its much more elaborate systems of response. When mind was developed to this stage of complexity the configuration of emotion emerged and gained scientific recognition through appropriate terminology. The percept or idea of a total situation, event or object first made this possible, and probably in the following order: first, the percept or direct apprehension, and then the idea of situations not physically present or relationships not physically apparent.

Many attempts have been made to answer our main question in terms of bodily processes of almost innumerable sorts. We have already indicated some of these references in our historical survey. But it seems that no sooner is a physiological process scientifically investigated than it is seized upon by avid psychologists in explaining the emotions.

Here is the inventory: expansion and contraction of protoplasmic tissues; involuntary movement of pursuit and avoidance; extension and retraction of voluntary muscles; changes in respiration, in circulation, in blood pressure; reverberations in the visceral region; volumetric changes in various parts of the body through extension of the capillaries with blood; tumescence and detumescence of the sex organs; secretions of the endocrine organs and presence of their products and of hormones in the blood; changes in electrical resistance and in the output of electrical energy; appearance and disappearance of Nissl substance in the brain cells; alterations in the rate of metabolism. To try to account for the mental life or any phase of it solely and primarily in terms of bodily changes is ridiculous in the face of the history of thought. The extreme position in this regard is well illustrated by Berman's widely circulated book called "Glands Regulating Personality," and Clarence Darrow's doctrine that criminals have only their glands to thank for their misdeeds is an offshoot of this philosophy. But it all reminds one of Mercier's statement that this is like "putting beefsteak into a sausage machine and pulling out a sonata" and James's remark that we might as well look somewhere in the train of cars for the friendship that exists between the brakeman and the engineer.

Luckily, however, this extreme position has not been held by most experimental psychologists. It is a restricted group of behaviorists, modified or pure, that have made the emotions equivalent to organic response. This group, however, leaves all consciousness as direct human or lower animal experience also out of account, so we have nothing else to expect from them if they are at all consistent. Our position, however, is as much at variance with that which attempts to *explain* emotion wholly in terms of one or more bodily responses as it is with that which *describes* emotions by means of these same responses. As has been noted above, explanation can come, in part at least, from the genetic development of mind itself. We have seen that not only must mind possess the ultimate feeling of pleasantness and unpleasantness, but it must have developed to the stage beyond the point where simple sensory qualities are pleasantly or unpleasantly colored. It must have arrived at the plane of perceptual experience of objects, events, and relations between these before it can have emotions. When they are affectively colored and have certain widespread organic responses accompanying them we have the corresponding emotions.

We have noted that the bodily manifestation of emotion has had a long history; it dates back to phrenology, which tried to diagnose character through the contours of the head and the expressions of the face. Darwin gave it renewed emphasis through his work with animals. But it was brought to wide notice in 1884 through the dramatically expressed statements of William James, since embodied in the James-Lange-Sergi theory. Three investigators had independently come to approximately the same conclusion. As usual, the theory had long been "in the air." In a scholarly note,[11] Titchener presents a long list of writers, especially French writers like La Mettrie and Cabanis, who had anticipated James and to whom James curiously enough gave scant notice. James's position was that the percept of the object or situation was directly followed by an inherited organic response and only when the latter "reverberated in consciousness," *i.e.*, was felt as such, did the emotional experience arise. In his own words, "Our feeling of the same changes as they occur

[11] E. B. Titchener, "An Historical Note on the James-Lange Theory of Emotion," *Amer. J. of Psychol.*, 25: 427–47, 1914.

IS the emotion." In obverse form a few pages later on he says, "If we fancy some strong emotion, and then try to abstract from cur consciousness of it all the feelings of its bodily symptoms, we find we have nothing left behind. . . ." He arrays many facts and findings in support of this position.

Two negative criticisms were brought to bear on this proposition: the pleasant and unpleasant attributes of feeling were left out of the formula and furthermore, as Angell soon pointed out, everything depended on the temporal sequence of events which under the conditions could hardly be introspectable. It mattered most just when the emotional experience was felt; was it felt as emotional when the percept occurred at the beginning of the experience or later? The theory would be overthrown if it were clearly shown that the bodily response did not happen until the emotionally colored percept was fully under way. This is the attitude most psychologists took in connection with emotion. The situation as regards the inclusion of affection was amended by James in 1894 with the remark equivalent to: "You foolish critics, of course you should have understood me better." But that again spoils the picturesque formula.

It will be clear at this juncture that the bodily responses have an all-important bearing on the emotions and that their place in the general scheme of things must not be denied. The writer's protest is rather against making the mental fact of emotion as a livable experience equal to, or the same as, some chemical or mechanical change in the body. Since Driesch's[12] excellent work on the relation between mind and body, now in its third edition, one can no longer maintain even a parallel relationship between mind and body. Mental processes like emotion, perception, imagination, ideation and thought do not run parallel to corresponding neurological, muscular and glandular secretions, if by such parallelism an efficient causal connection is implied: mind working on the body or the body working on the mind. The relationship between the two is more satisfactorily likened to two sides of the coin. Ordinarily the two sides can not be seen at one time. You look at one side and you comprehend only the mind and then you look at the other side from another point of view and you understand only the body. Both can not be discussed or described in the same terms or from the same line of regard. This is known as the "aspect" theory and dates back 250 years to Spinoza. It is becoming more and more widely accepted to-day, and in its modern version has been advocated chiefly by Warren. What the coin is actually made of or which side is front and which is back are the most difficult questions of all time. From the author's point of view, the universe can be more readily translated entirely and exclusively in terms of experience, that is, into an objective idealism, than into anything else. That may be due, however, to the fact that he is a psychologist, not a physicist, and further to the fact that we all are mentally anxious to simplify the universe and to reduce it therefore to one and only one underlying principle, be that the *idea* of Royce or the *electron* of Weiss.

With this understanding, then, let us return to emotion. Experimental facts point first to the conclusion that throughout the entire gamut of our life of feeling, movement has played an important rôle from the biological point of view. In the lowest forms in which movement can take place, in the unicellular animals, like the amoeba, the vital tissue protrudes in the direction of favorable stimuli and withdraws from harmful stimuli. When we have reason to believe, then, that sensations are first differentiated off from a common senti-

[12] H. Driesch, "Mind and Body: A Criticism of Psychological Parallelism" (trans. by Besterman), 1927.

ency or generalized feeling, and when they are affectively colored as pleasant or unpleasant, movement is already tied up with the experience. When this movement is felt again as sensation it enriches the affective experience still further. Often, like the moth flying into the candle-flame, these movements lead to harmful results, but, on the whole, all along the line, reflexes have been built up in the more and more complex animal forms on the basis of withdrawal from the painful and harmful and the reaching-out after the pleasant and beneficial. Even to-day, with the great deposit of the experience of the race within us in the form of reflex and instinctive behavior and the added experience of our educators and our own experience to draw upon, we still are repelled by the ugly face of an individual, though he be a Socrates, and feel attracted to a beautiful woman like Lucrezia Borgia who may be nevertheless an undesirable member of society. The writer has wondered whether Socrates would have been condemned to drink poison hemlock had he been a handsome man. The public must be brought to an abnormal emotional pitch to sanction the execution of an attractive woman for high crimes committed.

And so the musculature has been developed along with the growing complexity of mind to express organic needs. The bodily development does not rest there. At the same time all organic processes have been geared into the mental life, even directly or indirectly the growth of cell tissue and the very last metabolic process in the life stream. If we learn anything from physiology today it is the growing belief in the intimate interconnection of all of our bodily parts and functions—the same principle that finally overthrew on the mental side the so-called faculty-psychology of separate and independent mental capacities. The healthy living individual is an integer. Since emotions for the most part are so old and have held such an important place in the adjustment of the body to all sorts of situations, they involve these bodily processes to an outstanding degree and to an unusual extent.

Not all of these bodily processes are felt directly in experience, but many of them are, and others are felt indirectly. The tensing of muscles, the flushing of the face, the dry lips, the chills up and down the spine, the moist palms, are among the numerous items reported by our observers in the laboratory. These items even when only vaguely felt complete and enrich the emotional picture. The pattern is formed out of this bodily background, and each different emotion from our preliminary experiments gives a different and yet consistent arrangement of these details. They add depth to the experience and make it intrinsically personal since they tie the objective situation to ourselves and our bodies. The movements executed in the playing of familiar musical selections no doubt add to the enjoyment of one of these selections when it is later heard, since the sensations attending the movement are, at least in the writer's case, recalled as images in memory.

All this may have seemed like wandering through a long and circuitous path. The writer's snythetic answer to the question of why we have emotions is: first, because we have a mind developed to the point where entire situations and events, together with their meaningful relations, can be directly perceived or imagined. Without the ability to cognize our surroundings on this level we could never have an emotion. Secondly, behind it all is our possession of likes and dislikes, pleasantnesses and unpleasantnesses, the whole affective coloring of life. And finally our bodily accompaniments, the entire list of processes enumerated above, the movements of arms and legs, facial expressions and the like, have not only a social value, but with those that are implicit and unobserved have a reflex value on ourselves, enriching the experience and relating it to an important part of ourselves, namely, our bodies.

TROPICAL LIFE FOR WHITE MEN

By JOHN H. WHITAKER
MALAYA TRIBUNE, SINGAPORE

Having lived for nineteen years in the tropics, in Singapore and in different parts of the Philippine Islands, I was naturally very much interested in the extracts appearing in *The Literary Digest* from an article on "Tropical Life as a Factor in Human Evolution," originally appearing in The Scientific Monthly from the pen of Professor Ralph E. Danforth, of Massachusetts. I was the more interested because the results of my observations and my own experience in the tropics have brought me to exactly the opposite conclusions reached by Professor Danforth.

The "stupid notion" that tropical conditions lead to indolence and degeneration in man no doubt "clings with surprising tenacity" because it is based upon actual facts. Professor Danforth is quite right when he says that many of us, after a survey of the venerable civilizations of the Nile, the Euphrates and Tigris (more semitropical than tropical, by the way), will be "inconsistent enough to say in the next breath that man degenerates in the warm countries," for he certainly does, if they are warm enough. Where are the sons of the great builders of those civilizations? Where are the descendants of the builders of the great temples of Yucatan, Indo-China and Java? If they exist at all, they are certainly degenerate sons of noble sires.

Professor Danforth, in his second paragraph, as quoted by *The Literary Digest,* apparently makes the *survival of the unfittest* in the tropics responsible for the present decadence there as compared with centuries ago, in which he opposes a famous scientific law now being generally recognized. Is it not the fact, however, that except as new ideas carrying moral force have come at various times to stir tropical peoples into temporary activity, there has been a general decadence of the whole race in the past, whatever may be the tendency at present?

I quite agree with Professor Danforth's warm panegyric of the tropics. That is why I am here. But the fact is that the more tropical they are the more beautiful they are, because the more suitable for vegetation, though less suitable for man, particularly the white man. If Professor Danforth has any facts to show that the white man ever produced a magnificent civilization at sea-level near the equator, the world is awaiting that information. As a matter of fact, such lands are peopled by brown or black people. And "there's a reason." Professor Danforth tells us that man's "physical requirements are undoubtedly for a very mild and genial climate," with which statement I can quite agree; but would he call the equatorial regions "mild and genial"? I find by the official statement that the temperature in the sun here on New Year's Day, just passed, was 157 degrees Fahrenheit. Is that any more "genial" than the thirty degrees minimum which I found at San Diego, California? Or is it any more "mild"? These terms should be used circumspectly. Just as the white man has had to take centuries to fit himself (or rather to become fitted by the conditions surrounding him) to life in northern climates, just so has the brown or black man survived because he has grown to

conform to local conditions. His ancestors or his predecessors, whichever they may have been, were very different men from the equatorial man of to-day. They did wonders, which man can not do in the tropics and survive. The result?—a race which is wise enough to take bountiful nature as a kindly mother and not a harsh taskmaster.

Professor Danforth gives away his whole case when he says, according to the *Digest*, that "increasing numbers of folk with good heredity will probably colonize the pleasanter regions of the tropics, at moderate altitudes." When you get into these altitudes you are not where the great civilizations of which he writes were, neither are you where the great masses of people to-day are, where there is industry or avocation for "folk of good heredity," or where there is any real object for such folk to migrate. If Professor Danforth wants to argue that tropical life is good for the white man, because it is "mild and genial" (157°), let him base his arguments on those parts of the real tropics, such as Singapore, where man throngs the seacoasts.

We are told that we may rise above the dusty streets, if we only "plan aright." But if this is a good place for the white man he must take conditions as they are, as he does at home. Few of us indeed can afford to build or even live in skyscrapers, far above the dusty roads. I live myself in the third story and find dust on my mirror when I rise every morning in the dry season. If the tropics are so good for the white man, why these extraordinary precautions to rise above the dusty streets? We don't do it at home.

In conclusion, a few of my own observations will suffice to show the effect of tropical life upon white and other peoples. In the Philippine Islands, for instance, there is a variety of tribes, mostly of Malayan stock. They all, with one exception, look much alike when dressed alike, but there is a great difference in their characteristics. The Visayan, who lives in the southern islands, is slow and easy-going, with little ambition and no initiative. Wherever this is not true, there will be found to be an admixture of Chinese or other alien blood, comparatively new to the country. The most industrious, the most pushing, the most ambitious of all the tribes in the Philippines is the Ilocano, which furnishes nearly all the emigrants to the Hawaiian Islands and to the United States. Their habitat is in the northeastern part of the Philippine group, where they are many degrees farther from the equator than the Visayans and also face the strong breezes which sweep across the Pacific. Yet the two are brothers in blood.

The habit of running amuck (in Malay amok) is a characteristic of all peoples of the Malay race living near the equator, but is unknown among the same peoples far from the equator. It is certainly a characteristic superinduced by the rays of the torrid sun. The same rays have sent many a white man crazy, some of whom I have personally known. In fact, I dare to assert that we would every one of us go crazy if we lived under the same conditions as the Malay. Every white man who lives at sea-level near the equator learns that he has to wear a specially constructed hat to protect his gray matter from turning black, figuratively if not literally.

Is it a good place to encourage the white man to settle in, when he has to exercise every sort of precaution to preserve either his physical or his mental health? I trow not, because there are few of us with sense enough to be constantly on the alert to take the essential precautions. The result is that the ordinary white man deteriorates here mentally, physically and morally. This is

shown by many facts. For instance, it is known to every white man here that death comes with a suddenness unparalleled anywhere else on the globe. It is an old saying, repeated to newcomers, "You are at work to-day, sick to-morrow, dead the next day and buried the day following." Why? Simply because the white man's body is so weakened by the debilitating effects of tropical life that he falls a ready prey to a disease which he would soon shake off in colder lands. The first mental faculty lost is the remembrance of names. I have lost that completely here and on going back to the United States recovered it fully in less than a year. The will power is weakened and this leads to vices which aid the climate in bringing premature decay. The children of white parentage do not get reddened, as one would suppose who has never been here (for they do at home in hot weather), but on the contrary they become a chalky white, which betrays sadly impoverished blood. Even adults frequently get the same way. Once you get that way there is no regaining a healthy color without a return to a colder climate.

A final bit of evidence that I would cite to prove the inevitable deterioration of the white man in the tropics is this: His descendants, when he has mingled his blood with any of the native races, will become more or less degenerate (if they remain in the tropics), in almost exactly the proportion in which they retain or lose the paternal color. I am aware that there are many exceptions to this rule, and some may attempt to dispute it altogether, but it is the settled conclusion of long years of study and personal investigation.

SOME INSTANCES OF SUPPOSED SYMPATHY AMONG FISHES

By Dr. E. W. GUDGER

AMERICAN MUSEUM OF NATURAL HISTORY

THAT the higher animals, birds and mammals, frequently manifest sympathy for their wounded comrades is a matter well known to students of natural history. Most of us have read how the comrades of a wounded elephant will support him on either side while he is endeavoring to make his escape. I am able to quote just here from the well-known naturalist, Abel Chapman, in his book "Savage Sudan" (London, 1921, pp. 157 and 283) two definite cases of similar kind. He had wounded a lechwi (*Onatragus megaceros*), and thus describes what took place after one of its fore legs had been broken by a shot:

> He had already stopped twice, and appeared on the point of abandoning further effort, when his sable pal, with at least one of their tawny consorts, deliberately turned back to the rescue of their disabled friend—surely a beautiful example of animal sympathy. Supported thus on either flank, for a while my quarry gamely struggled onwards; but it soon became obvious that the effort was beyond his ebbing strength. Then the gallant auxiliaries had perforce to abandon their attempt, and soon the whole herd proceeded at full speed inland.

Chapman put the buck out of his misery and then shot the other buck which had again come back to assist its comrade. Later he wounded a baboon and he thus described the action of its companions:

> Suddenly the rest of the troop, which meanwhile had utterly vanished, reappeared, two or three supporting their stricken leader on either side. Being now still more reluctant to fire, the result was that the ambulance squad reached a patch of thick bush and therein I lost them. A similar incident occurred the following year on the Dinder River.

Coming nearer to our subject, at least so near as to a water-dwelling mammal, the grampus, R. J. Daniel ("Animal Life in the Sea," London, 1925, p. 85) quotes from a writer named Buchanan that in hunting the grampus from a small boat in the Mediterranean:

> One was killed and a second wounded by a harpoon, whereupon two others ranged themselves on either side of the boat, and attempted to crack the timbers by squeezing with all their force, and in this plan they would have succeeded if the dead grampus had not been already hauled alongside; this acted as a fender and raised the boat out of the water a little so that it avoided the fury of the attack.

This is all very well, says the reader, for "You are dealing with the higher vertebrates with well-developed brains; but what about your fishes, cold-blooded vertebrates, the lowest of the back-boned tribe?" Let me answer first of all in general terms that while they are the lowest of the vertebrates their brains and nervous systems are far from being rudimentary structures. Nor are they wholly devoid of intelligence. This can be attested by any one who has tried to lure from his hiding place under a stump or a shelving rock a wary old trout who by reason of his size and cleverness is acknowledged master of the particular "hole" in the stream wherein he has taken up his residence.

At the Tortugas (Florida) Laboratory of the Carnegie Institution of Washington, a school of gray snappers (*Neomaenis griseus*) used to play around the western dock to feed on the scraps from the kitchen. When any one approached, these fish would turn slightly on one side,

would cast a cool and wary glance at the intruder and slowly move off. I have elsewhere[1] described their behavior in some detail. None was ever taken with a hook in the daytime. Many years before, Dr. C. F. Holder fished for gray snappers at Tortugas and only occasionally hooked them even when he used a long slender wire leader *embedded in the sand*.

The most wide-spread manifestation of supposed sympathy among fishes, and one witnessed by many travelers and possibly by some of my readers, is that of the pilot fishes, *Seriola zonata,* and *Naucrates ductor,* small mackerel-like fishes which are frequently found associated with sharks and which seemingly show great excitement and distress, manifested by dashing wildly about, when the shark is drawn to a vessel or wharf and is pulled on board. This is of course open to the construction that the shark, the pilot fish's home, is being taken away from him, hence his excitement and apparent distress. However, so far as manifestations of pity or sympathy among fishes are concerned, I had given no attention to the matter until the following incident was noted. At Tortugas in 1913, while trolling one day between Loggerhead and Bird Keys, I had a heavy strike. Pulling in the fish hand over hand I brought to the surface a large barracuda. Remarkable to say, this had close on either side a barracuda nearly as large as itself. These had their heads in the region of the right and left pectoral fins of the hooked fish. It looked as if they had laid hold behind on the breast fins of their captured friend and were helping him hold back, and chief engineer John Mills, who was with me at the time, so averred to the men's mess. And it must be confessed that it did seem as if all three fish were pulling back on the line. When the captive was brought near the boat its two companions disappeared.

Record was made of the matter and later an account of the incident was published in an extensive monograph on the barracuda, but without any attempt at explanation. In fact nothing further was thought of the incident until, as editor of the index volume of the "Bibliography of Fishes," I chanced on certain references to seeming manifestations of sympathy in fishes. Notes were made of these and of like instances in various books on fishes and fishing, and were filed away. Later, particular accounts were sent in by friends and correspondents who learned of my interest in this matter. And now it seems worth while to bring these together in an article bearing the title above.

Edward Jesse in his "Gleanings in Natural History" (vol. I, London, 1832, p. 75) gives the earliest record known to me of what might possibly be conjectured as a manifestation of piscine sympathy. During the spawning season he caught a female pike, whereupon another fish (presumably a male) followed her to the edge of the water and refused to be driven away.

The next account I have is from the pen of Leon Bucek,[2] who in 1879 was an eye witness to the following incident. A friend of his had an aquarium inhabited by a number of small turtles. These he fed on gudgeons, and Bucek describes carefully how the turtles would stalk the gudgeons. Then he adds:

> Happening one day to be passing the tank, I noticed a little fish in imminent danger of being devoured in this way. I thought to myself, "Poor little devil, it's all up with you!"—when I saw swimming up an older and larger gudgeon, which also, it seems, had noticed the murderous intention of the turtle. "What will happen now?" we asked one another. The

[1] E. W. Gudger, "Notes on the Behavior of the Gray Snapper (*Neomaenis griseus*), a Common West Indian Fish," *Natural History*, 1924, 24: 253–254. Fig.

[2] Leon Bucek, "A Brave Gudgeon," *Fishing Gazette*, London, 1879, 3: 544. Translated from *Deutsche Fischerei Zeitung*, Oct., 1879.

gudgeon did not keep us waiting long for the answer. With extraordinary exertion and powerful strokes of the tail he squeezed himself past the turtle up to the poor victim, covered him with his own body, and then, whilst splashing violently in the water, placed himself close to the young fish, pushed him forwards until he was in a more open part of the tank and out of danger—and so saved him.

R. B. Marston,[3] the well-known angler and writer on angling matters, was led by Bucek's story to relate the following incident which happened to him personally:

We noticed two very large chub swimming close together near the surface; . . . and we let . . . our cast . . . drop gently on the water just in front of the larger fish; he rose leisurely, opened his portmanteau-like mouth, and a slight . . . movement of the wrist fixed the hook in his leathern lip. After one grand rush he soon gave up struggling and came to the top again . . . we were playing him gingerly . . . , when to our astonishment the second chub now appeared on the scene, came up to the captive, and commenced swimming around him in an uneasy and most persistent way. We were so convinced from its actions that the second chub knew its companion was in danger, that we almost expected to see it lash the line with its tail to release it—indeed, we were so convinced it would come to the rescue that we threw a dead stick at it to frighten it away; it disappeared for an instant, but only to return apparently more anxious than ever. This lasted about five minutes, when chub number one . . . got the line fast . . . in a thorn bush under water. . . . There was our prize, and there was our line hopelessly entangled, and to our utter astonishment there was chub number two swimming close to the bush and not a yard from the place where we were standing and splashing in the water. The only chance of landing number one was to raise the bush bodily from the water until he could be grasped with the other hand. In attempting to do this, a thorn must have pricked him, at any rate he made another dash and we had the mortification and satisfaction of seeing him sail away free—mortification at losing a five-pound fish, and satisfaction at seeing him and his faithful friend depart together into the depths of the pool.

Francis Day ("The Fishes of Great Britain and Ireland," 1880, vol. I, p. 229) says that a school of mullets were once caught in a net at Mevagissey. Some jumped over the net while others escaped under the lead line. However, one became enmeshed. "When this was done, another came and laid beside it, and nothing could drive it away. In short, all escaped but these two." To any one who, like myself, has tried to take these bold, vigorous fish in a net, this action of these two mullets is very significant.

H. S. Thomas in his "The Rod in India" (London, 1881, p. 65) records many keen observations on the habits of fishes, and in discussing the question as to whether fishes can communicate with each other writes as follows:

Many anglers will have noticed that in playing one fish it is not infrequently followed about through all its struggles by its pair fish in the case of the murral [the snake-headed fish, *Ophiocephalus*] or by a crowd of fishes as with the Mahseer [*Barbus tor*]. Why is this? Is it merely that the others are curious? If so what is it that they are curious about? Is it about the strange demeanour of the played fish? They follow it very closely. Or can it be that the hooked fish has expressed astonishment or fear, or has asked for aid?

George A. B. Dewar, in his book "Wild Life in Hampshire Highlands" (London, 1899, pp. 126–127), quotes a Mr. Moss, who used to fish the River Test, that one season many trout were suffering with the fungus disease. He specifically noted one fish of about two pounds in weight whose head was so covered with fungus that it was evidently blind. Accompanying this fish was a smaller fish without trace of the fungus. Repeatedly the observer noted that when the sick trout came too near the edge of the stream, "the healthy one would swim inside and gently push the former in the side with its nose, and so get it out into deeper water." He was persuaded that the healthy fish had taken charge of the sick one.

Next to be quoted is an Indian angler, W. A. Wallenger,[4] who emphasizes

[3] R. B. Marston, "A Devoted Chub," *Fishing Gazette*, London, 1879, 3: 544–545.

[4] W. A. Wallenger, "Curious Behavior of a Mahseer (*Barbus tor*)," *Journal Bombay Natural History Society*, 1908, 18: 690.

Thomas's reference to the mahseer. A large specimen had been hooked and:

As, half drowned, he was brought within view, we saw *to* our surprise that the captured fish was not alone! A companion of about the same size was at his side and it was only the vision of a landing net a foot from the end of its nose, some five minutes later, that induced this remarkable companion to disappear. It looked all along just as if the captured fish was receiving that support which a fellow creature much higher in the scale of Natural History has every right to look for, and the circumstances may, I hope, be considered sufficiently interesting and unique to deserve this bare record.

Sometimes the manifestation of what seems to be sympathy between the fish and its companion takes the form of an attempt to free the captive. Thus Edward R. Hewitt found it ("Secrets of the Salmon," New York, 1925, p. 147). Here is his account of what happened:

One of the fish made a rush, took it [the fly] and was hooked. He did not jump but tore about the center of the pool. The others seemed much excited, and one of them followed him alongside for some distance and then seemed to make up his mind what was the matter. He swam ahead of the hooked fish and then made a complete turn like a somersault right at the nose of the hooked fish; his tail of course hit the leader and broke it off. The whole action took place within thirty feet and we could see it all plainly. I wonder if some of the fish we lose where we can not see them, do not get away in some such way, by the help of others. This case did not look like an accident.

It is not generally known that Zane Grey, the novelist, is also possibly the greatest marine angler of our day. In various of his works on sea angling he has related that sailfish have attempted to bite his lines in two or to cut them with their fins. In his "Tales of Fishing Virgin Seas" (New York, 1925, pp. 153–154), he tells how his brother had a sailfish hooked when another came up and tried to bite his line. Of this and other like performances he says: "I had not the slightest doubt that it [the biting on the line] was caused by the instinct of the sailfish to free its mate." In New Zealand waters, a marlin swordfish swam rapidly back and forth under his line in an apparent attempt to cut it and free its hooked companion.

Mr. Van Campen Heilner, of the department of ichthyology in the American Museum, a fisherman of wide experience, has made numerous observations on cases of seeming sympathy among fishes, and has been good enough to prepare the accompanying statement for me. He writes as follows:

Anent the subject of sympathy among fishes, I have observed on various occasions that fishes evince something which if not actual sympathy may be closely akin to it.

Once while fishing on the Florida Reef I hooked a sailfish. Immediately the water astern seemed to swarm with sailfish and I observed that my quarry was accompanied by four or five others. These rushed about at the surface in the greatest state of excitement and one fish in particular was observed by all on board to leap into the air and fall across the line on two occasions—apparently in an effort to break it and free his companion. It may be however that this was purely by chance.

It is well known that when fishing for amberjack it is an easy matter to hold the entire school astern of your boat indefinitely as long as you have one of their companions on your line. Off will rush your fish and off will rush the school with him. As you bring him back to boat, they accompany him. Before taking him aboard, however, your companion should make fast to another and the performance will be repeated. As long as you have a *struggling* fish on your line, the school will remain and it is often possible in this manner to catch the entire school.

It has been my experience that a wounded fish or any fish which is acting strangely or unnaturally *always* attracts others. Whether this is because other fish see an easy opportunity for capturing food, whether they believe their companion has seized a piece of food which he has difficulty in swallowing and which they may be able to snatch from him, or whether they rush toward him in a spirit of sympathy, I am not prepared to state. It may be they are seized with a kind of "mob psychology" which they are unable to resist and rush hither and thither in a state of greatest excitement. It is the writer's opinion that food is the basic cause of strange actions akin to sympathy among fishes. I can not think of a

single incident in my experiences when I could attribute unusual actions on the part of fishes to downright intelligence.

One of my former students, Dr. Louise M. Perry, of Asheville, N. C., a keen observer of natural history matters, has written me as follows on the subject in hand:

> In April, 1926, I had an interesting experience with a couple of cabios (*Rachycentron canadus*). Two of us and a guide were fifteen miles off shore [near Captiva, Florida] after kingfish. We were taking them on No. 5 Wilson spoons, and had observed a pair of large fish following the boat. We thought that they were sharks until one took my spoon, when we recognized them as cabios. For fifteen minutes the big fellow fought hard while the second fish kept so close to him and followed his movements so accurately that I was not certain which fish was being played until he was drawn nearer the boat. When he was close at hand, he made a final struggle for his liberty with the smaller fish close beside him, swimming in small circles and following right to the side of the boat when my fish was gaffed and hauled aboard.

Last of all I have the following account to present from a correspondent of mine in the South Seas, Mr. Donald G. Kennedy, of Vaitupu, Ellice Islands. Mr. Kennedy has interested himself in the fishing for the oilfish, *Ruvettus pretiosus*, a mackerel-like fish taken off the reefs of coral atolls at depths of from 80 to 250 fathoms (480 to 1,500 feet). After commenting on the fact that this deep-sea fish seems to be able to survive the low surface pressure—does not die with its air bladder distended and protruding from release of pressure on being drawn to the surface—he adds further that:

> All that I have seen caught were certainly very much alive when drawn out. Furthermore, some three years ago, fishing from a boat, I hooked a *Palu fala* (*Ruvettus pretiosus?*) at about 150 fathoms. He came up in the usual fashion, but I was greatly surprised to see lying alongside, as though tied to him, but quite free of both hook and line, another *Palu fala* of about the same size. The hooked *Palu*, as his head was drawn out of the water, began to struggle violently. The other immediately parted from him and swam once round the boat. One of my men attempted to spear him but was unsuccessful. He dived soon after and quickly disappeared. I attempted to elicit information as to whether this occurrence was common, but was met by a mask of that obtuseness which the Polynesian knows so well how to assume.

The data as it has come to me on supposed or inferred cases of sympathy in fishes has been set before the reader. Careful search through the general literature of fishes would probably bring to light other instances like those narrated above. Such a search would be tedious to say the least. I have, however, gone through all the recently published books, both English and German, accessible to me, dealing with animal psychology, only to find that the attribute of sympathy in fishes has not been dealt with by any of them.

However, to one who has for many years studied the habits and the behavior of fishes in their native element, and who has some knowledge of the vast literature recording the observations of others on these same matters, it is somewhat difficult not to give a humanistic interpretation to the phenomena herein set forth. For many of the things that fishes do and many of the habits that they have developed are remarkably like similar practices found among higher animals—especially in matters of nest building and the care and protection of their young.

But fishes are the lowest division of the vertebrate group. In them the brain, especially the cerebrum (the center of mentality), is poorly developed in comparison with that of the bird or the mammal. They are, in keeping with their low position, singularly indifferent to pain. Their brain powers have been developed mainly toward three ends: the procuring of food, the avoidance of

serving as food for other animals, and the care of eggs and young—in short, to the one great purpose of perpetuating their kind. However, fishes do show the beginnings of mentality, of mind, but in a very embryonic fashion as is to be expected. And it is perhaps going too far to attribute to so lowly organized an animal as a fish the high mental quality of sympathy. It seems better to reserve this attribute for the higher animals, and hence to entitle this article "Some Instances of Supposed Sympathy Among Fishes."

THE EFFECT OF INSULIN ON FISHES

By Professor IRVING E. GRAY

TULANE UNIVERSITY

ALTHOUGH considerable study has been made of the action of insulin, since its discovery in 1922, very little is known concerning its behavior with respect to the lower vertebrates. It is to be expected, since there is a clinical application, that the greater proportion of research upon the properties of insulin would be done on the warm-blooded animals, particularly the mammals. Almost every one is more or less familiar with the fact that a large amount of human suffering has been relieved either directly or indirectly as a result of these researches. While there are not such important practical applications attached to a study of the action of insulin in fishes and the other cold-blooded vertebrates, the results are none the less interesting. However, before discussing its effect on fishes it might not be out of place to make a few statements concerning the action of this antidiabetic hormone on the mammals.

We all know that insulin causes the blood sugar of man and the other mammals to be lowered, and for this reason is used in the treatment of diabetes. It must be given hypodermically, due to its destruction by digestive enzymes when taken by mouth. It is also recognized that an overdose will lower the blood sugar to such an extent that abnormal behavior results. This abnormal behavior in some cases manifests itself in the form of convulsions which are fatal unless glucose is administered. Rabbits, for instance, get convulsions when the blood sugar is reduced below 0.045 per cent. The rapidity with which convulsions appear after insulin is administered depends largely on the size of the overdose given. They may be produced within half an hour by a sufficiently great dosage. The number of units of insulin to be used is determined by the weight of the subject to be treated.[1]

Any study of the physiological action of insulin must generally include also a study of the blood sugar of the animal or animals concerned. If we make a study of the blood sugar of a representative number of different types of teleost fishes we find that not only is there an extremely wide variation in the percentage of sugar among different species, but that there is also considerable variation among individuals of the same species. Where the individual variation between fishes of the same species is great, it becomes necessary to use a fairly large

[1] Insulin as sold by drug companies has been standardized and may be obtained in bottles of known strength, *i.e.*, there are a definite number of "units" of insulin per cc of liquid. A "unit" of insulin is described as being one third the amount of material required to lower the blood sugar of a two-kilogram rabbit, which has been fasted for twenty-four hours, from a normal concentration (0.118 per cent.) to 0.045 per cent. over a period of five hours.

number in determining the average. In general there is greater variation within species that have high sugar in the blood than those that have a relatively small amount.

The average blood sugar of the sixteen species of marine teleost fishes studied varied from less than 0.010 per cent. in the sluggish goosefish, to well over 0.070 per cent. in the more active fishes, such as the bullseye mackerel, menhaden, butterfish, etc. In general we may say that the active fishes have a higher percentage of sugar in the blood than do the sluggish fishes. For convenience we may arbitrarily divide the marine teleosts into two groups, according to the amount of sugar present in the blood. In group I would be placed those whose blood sugar averages are above 0.040 per cent., while those with sugar below 0.040 per cent. would constitute group II. On this basis the first group —those with relatively high sugar— would be made up of fishes that are moderately or extremely active, and would include the bullseye mackerel, (*Scomber colias*); common mackerel (*Scomber scombrus*); bonito (*Sarda sarda*); menhaden (*Brevoortia tyrannus*); butterfish (*Poronotus triacanthus*); scup (*Stenotomus chrysops*); rudderfish (*Palinurichthys perciformis*); eel (*Anguilla rostrata*), and others. On the other hand, group II would consist of the more sluggish fishes, such as the toadfish (*Opsanus tau*); goosefish (*Lophius piscatorius*); puffer (*Spheroides maculatus*); sand dab (*Lophopsetta maculata*); cunner (*Tautogolabrus adspersus*), and sea robin (*Prionotus carolinus*).

Now if we administer insulin to representatives of these two groups of fishes, the resulting reactions of those in each group are entirely different. If insulin is given those in the first group, for example, menhaden, mackerel or scup, we find that after a period of time, depending on temperature and the species used, insulin shock is produced which is comparable to convulsions produced in mammals. The effect of the insulin manifests itself in the peculiar actions of the fishes: loss of balance, spiral swimming and rapid darting about the aquarium followed by a period of inactivity. A few fishes have been observed to become much darker in color.[2] In some instances violent convulsions may be developed which, as in the case of mammals, are fatal unless glucose is administered.

The time required for insulin shock to develop after the injection depends, apparently, upon the metabolic activity of the animal. This has been pointed out by Huxley and Fulton[3] and by Olmsted,[2] who have studied the action of insulin on frogs and fishes. Among the cold-blooded animals changes in temperature of course influence the metabolic activity of the animal, so that, indirectly at least, the rate at which convulsions will be produced will depend on temperature for any one particular species of fish. The metabolic activity of all fishes is not the same; consequently different species of fish, at the same temperature, will have different reaction times. There is even more or less individual variation in reaction time among fishes of the same species. At 21° C. menhaden and the common mackerel developed convulsions in from one to three and a half hours after the insulin was administered. The bullseye mackerel required from three to six hours; and the scup about twenty hours. The scup is not nearly as active a fish as the others just mentioned. Contrary to expectation, a large overdose of insulin does not bring about convulsions

[2] J. M. D. Olmsted, *Am. Jour. Physiol.*, 1924, 69: 137. I. E. Gray, *Am. Jour. Physiol.*, 1928, 84: 566.

[3] J. S. Huxley and J. F. Fulton, *Nature*, 1924, 113: 234.

in fishes quicker than a small one. As long as an overdose is given it seems to make no difference about the amount.

If we compare the blood of the normal fishes with those that have been given insulin we find that a remarkable reduction in the blood sugar has taken place in those receiving the insulin. The sugar of the blood of normal menhaden averages about 0.073 per cent.; common mackerel, about 0.064 per cent.; bullseye mackerel, 0.090, and the scup, 0.060 per cent. Similar fishes, treated with insulin and bled while in the midst of convulsions, showed reduced sugar values of from 0.010 to 0.020 per cent. This reduction in the blood sugar is comparable to the reduction in mammals following an overdose of insulin, except perhaps that in mammals convulsions begin before the blood sugar has fallen to as low a level as it does in fishes. It can not be definitely stated how low the blood sugar of fishes must fall before convulsions develop. Two mackerel bled when the effect of the insulin was just beginning to manifest itself had blood sugar values of 0.031 and 0.032 per cent. These fishes, however, had not reached the convulsive stage. It is possible that there is a threshold for each species.

Relief from convulsions may be obtained by giving injections of glucose. Occasionally one injection of glucose is insufficient, and the fish after being apparently normal for several hours goes into convulsions again. Permanent relief may be obtained, however, if sufficient glucose is administered. A number of brown trout experimented upon required from two to four injections of glucose to give complete recovery.

Turning now to a study of the action of insulin on the fishes of the second group—those which are more or less sluggish and have relatively low blood sugar—we get entirely different results. If, for instance, we inject into such fishes as the puffer, toadfish, sea robin or cunner, strong overdoses of insulin, we find no visible reactions occurring. No convulsions develop nor are there any external evidences that insulin has any effect upon these fishes. The puffer and toadfish were studied more extensively than were the other relatively inactive fishes; and to large numbers of these, doses of from five to fifteen units of insulin were administered at varying intervals of time, with apparently no effect. There can be no doubt that a sufficient quantity of insulin was given since these fishes weighed only slightly over one fourth of a kilogram. Based on the responses of mammals even a single five-unit injection would have been a rather severe overdose and theoretically should have produced a reaction if the animal was at all affected by insulin. Correlated with their non-response to insulin, we find that the normal untreated fishes of this group have low blood sugar. The normal sugar of the blood of the puffer averages about 0.024 per cent., while that of the toadfish averages only 0.013 per cent. When the normal sugar level lies as low as this it is difficult to determine if insulin has any reducing action. It will be noted that the normal sugar of the blood f these fishes lies at the level of insulin-reduced sugar in the blood of the active fishes. That is, some fishes of group II normally have blood sugar as low as or even lower than the level at which fishes of group I get convulsions. The goosefish at times shows only a trace of sugar in the blood, and it was never above 0.010 per cent. in the specimens analyzed. One can readily see the difficulty encountered in trying to find if insulin will reduce the normal sugar of a fish of this sort. The goosefish is rather an extreme case and had the lowest sugar of any fish so far studied. The sea robin normally has about 0.035 to 0.040 per cent. of sugar in the blood. One specimen bled twenty-four hours after being given insulin had a blood sugar of 0.017 per cent., but no external

evidences that insulin had been administered were noted.

The sluggish fishes are not the only cold-blooded vertebrates not to be affected by insulin. Turtles and snakes apparently show no ill effects when given large doses. Why it is that some animals are so markedly affected by insulin while others are not influenced at all can not be stated with certainty at this time. It may be that animals with low metabolic activity have a different mechanism of controlling sugar metabolism than the more active species. Among the fishes a few interesting correlations can be made that in the future may throw some light on the subject. It has already been pointed out that the most active fishes have the highest blood sugar and are the ones to be affected by insulin. These active species are also our best migrating fishes, and travel together in schools, while the sluggish ones with low sugar migrate relatively little and usually travel by themselves or in small groups. Whether any significance can be attached to this correlation between activity, high blood sugar and migrating ability remains to be seen.

It is of interest to note that in many fishes insulin is not manufactured in the pancreas as in mammals, but there are islets for its production outside the pancreas in masses scattered about in the body cavity. Particularly is this true of the more sluggish fishes, such as the sculpin and the goosefish. This condition, if it exists in all sluggish fishes, offers another correlation and suggests problems that may be extremely interesting.

IN QUEST OF THE ORIGINAL REFLUX

By Professor D. B. KEYES
UNIVERSITY OF ILLINOIS

DISTILLATION and fractionation of liquids is one of the oldest unit processes in the history of chemical engineering. The modern still and fractionating column is a very simple apparatus. The underlying principles in its design and operation extend far back in history.

Figure 1 shows an example of a modern fractionating column and still used in petroleum refining. The basic features are, a heating coil at the bottom of the column, the entrance of the feed in the form of vapor or liquid at the side of the column, and a reflux condenser to return part of the condensed vapors to the top of the column. In this particular case perforated plates are used to bring the vapors in intimate contact with the liquid. Other types of plates are also used. The column operates as a counter-current scrubber or extractor. The liquid condensed at the top of the column is of

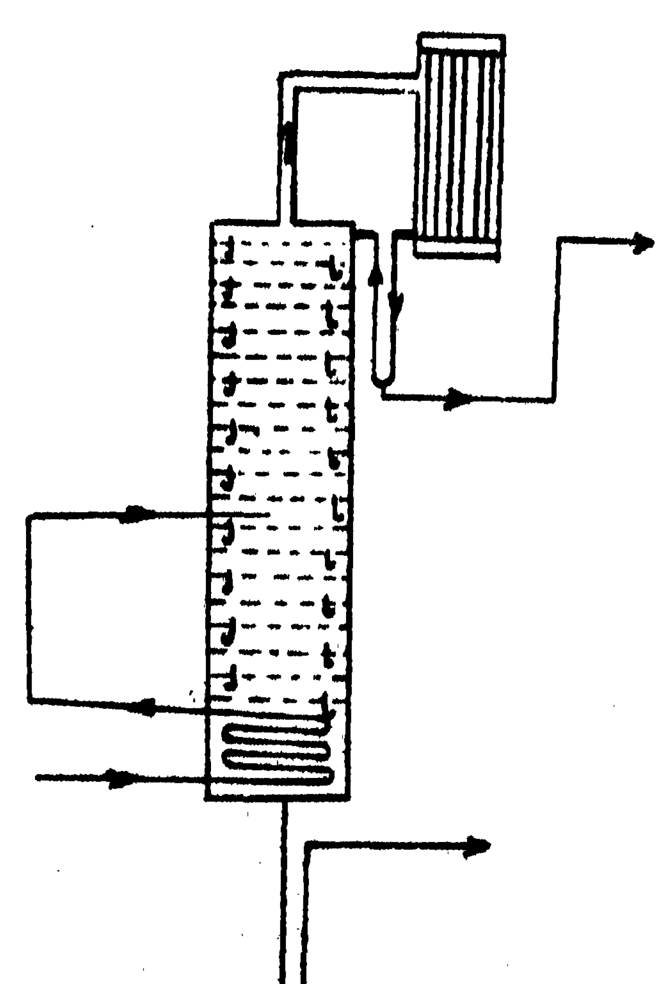


FIG. 1.

the same composition as the vapors at that point. This liquid passes down the column meeting the vapors produced not only in the bottom of the column but from the feed. The action is the transfer of the high boiling constituent from

the vapor phase to the liquid phase and the transfer of the low boiling constituent from the liquid phase to the vapor phase. The result is, the low boiling constituent comes out at the top of the column and is condensed, whereas the high boiling constituent is removed in the form of a liquid at the bottom of the column.

In looking over the fractionating columns that have been built only a few years ago in our oil refineries, we find that the basic requirements of this process have not been thoroughly appreciated. The reflux condenser has been left off and no indirect heat is supplied at the bottom of the column. An example of this type of fractionating column is shown in Figure 2. One

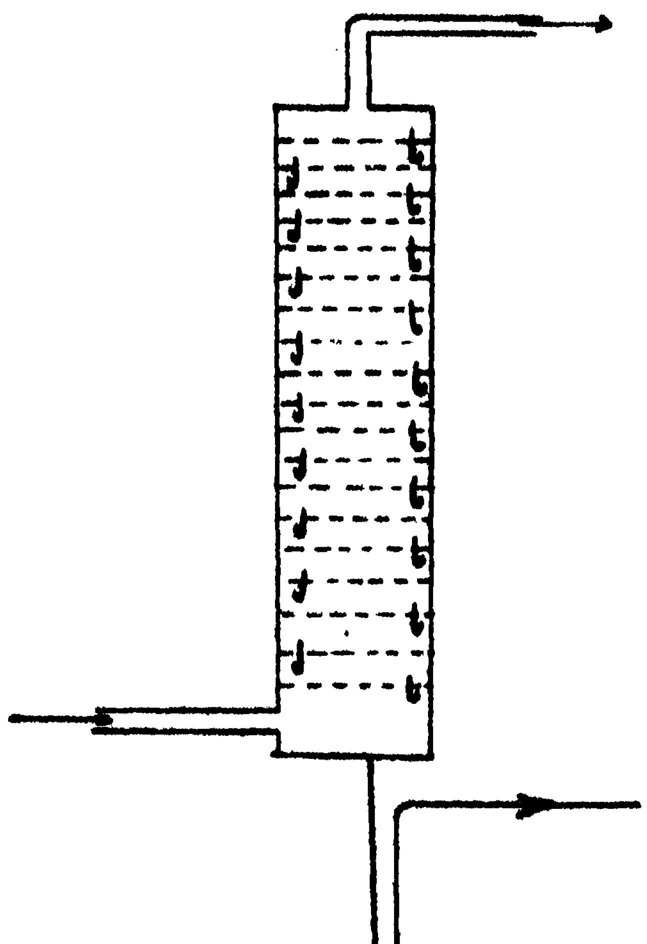


FIG. 2.

would, therefore, naturally assume that the reflux condenser was a modern invention. We find to our surprise that such is not the case; that all of these features shown in Figure 1 and Figure 2 have been known since the sixteenth century at least.

Dr. John French, of London, England, wrote a book in 1651 on the art of distillation. It will be of interest to look over some of the sketches in Dr. French's book and see how clearly he appreciated the fundamental principles of distillation and fractionation. Figure 3 shows

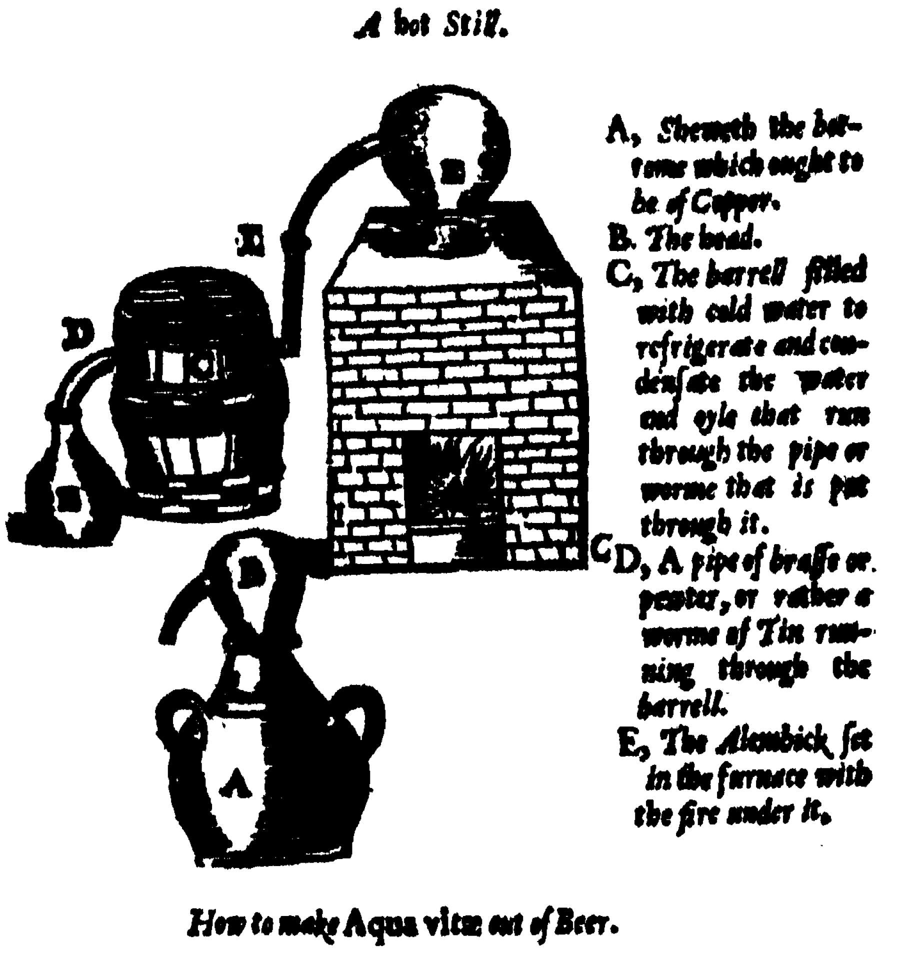


FIG. 3.

a common still of his day. It should be noticed that the still was heated indirectly at the bottom and that the distilling head was open to the air and, therefore, acted to a certain extent as a partial or reflux condenser. The total condenser consisted of a coil in the water barrel. In fact this still with its auxiliary equipment resembles very closely the moonshine stills used at the present time in our own highly modern and civilized country.

In Figure 4, Dr. French shows us the laboratory steam- or water-bath used

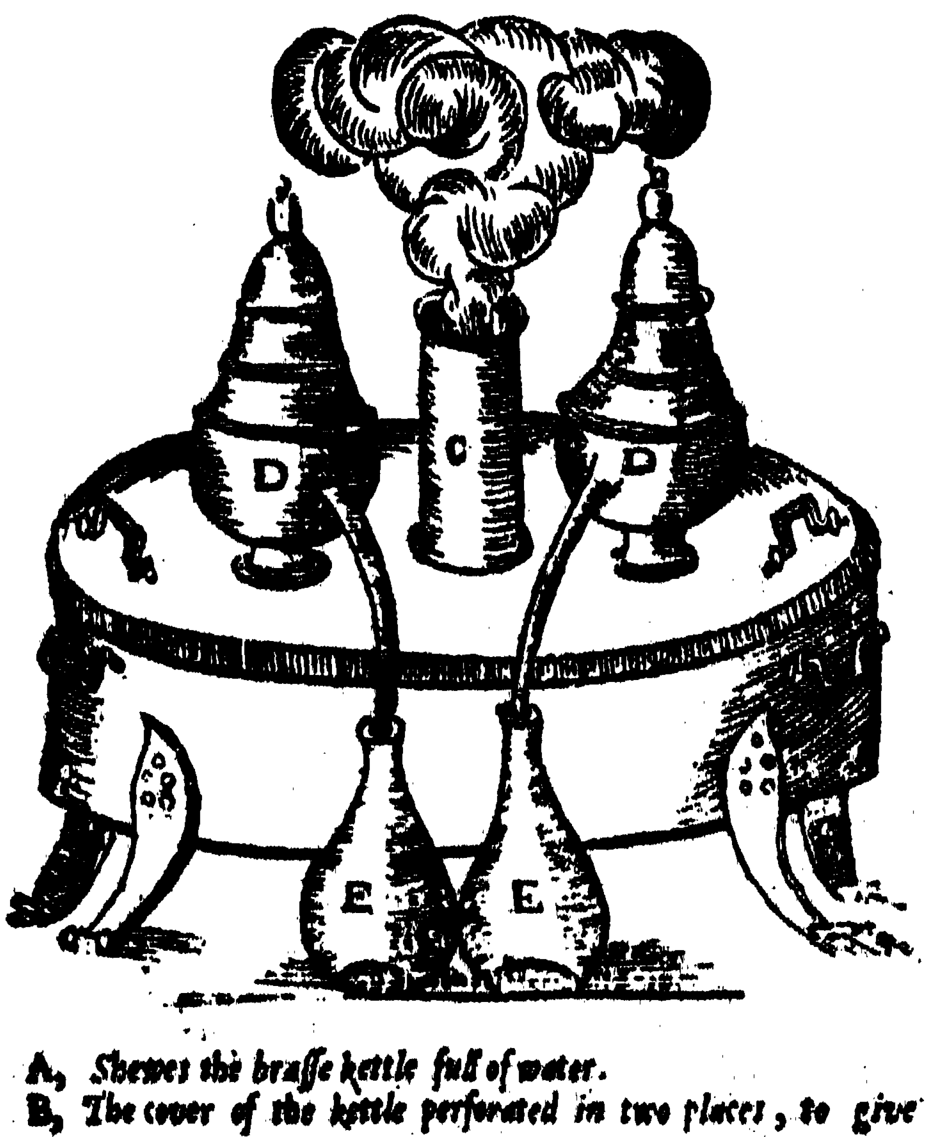


FIG. 4.

in connection with distillation. The still is heated by the boiling water within the bath and again it should be noted that the still head is outside and in contact with the cold air, thus producing the desired reflux. The steam-bath used today in our great institutions of learning shows no particular advantage over the one pictured in Figure 4. Dr. French liked to take full advantage of any cheap source of heat that he could. In Figure 5 is shown his scheme for

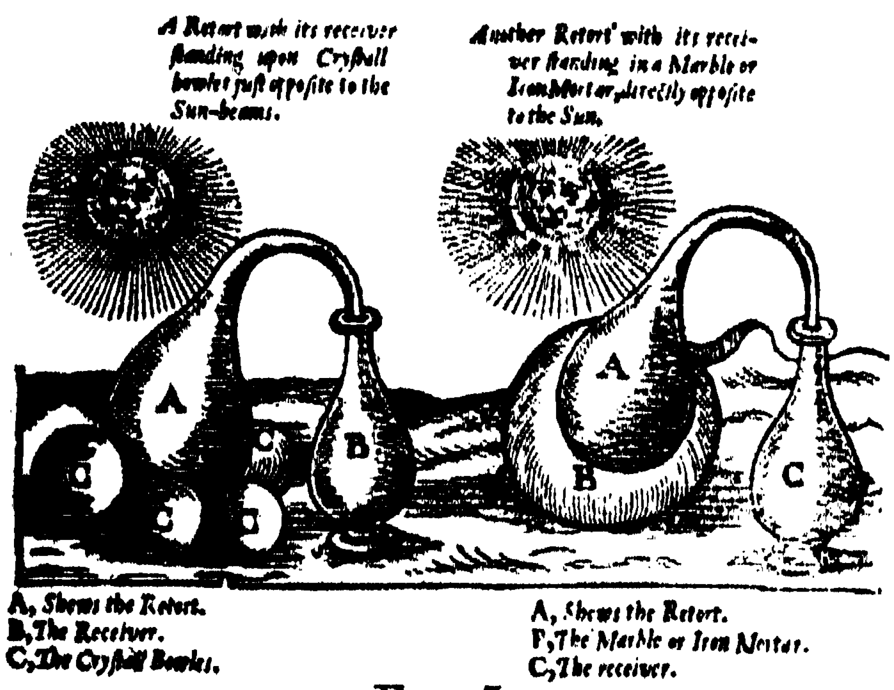


FIG. 5.

utilizing the sun's rays. The figure on the left has glass balls around the distilling flask. It should be noted that the flask is not completely embedded in the balls. On the right the balls have been replaced by a marble or iron mortar.

The simple art of steam distillation used so extensively in oil refining is thoroughly appreciated by Dr. French as shown in Figure 6. The first barrel

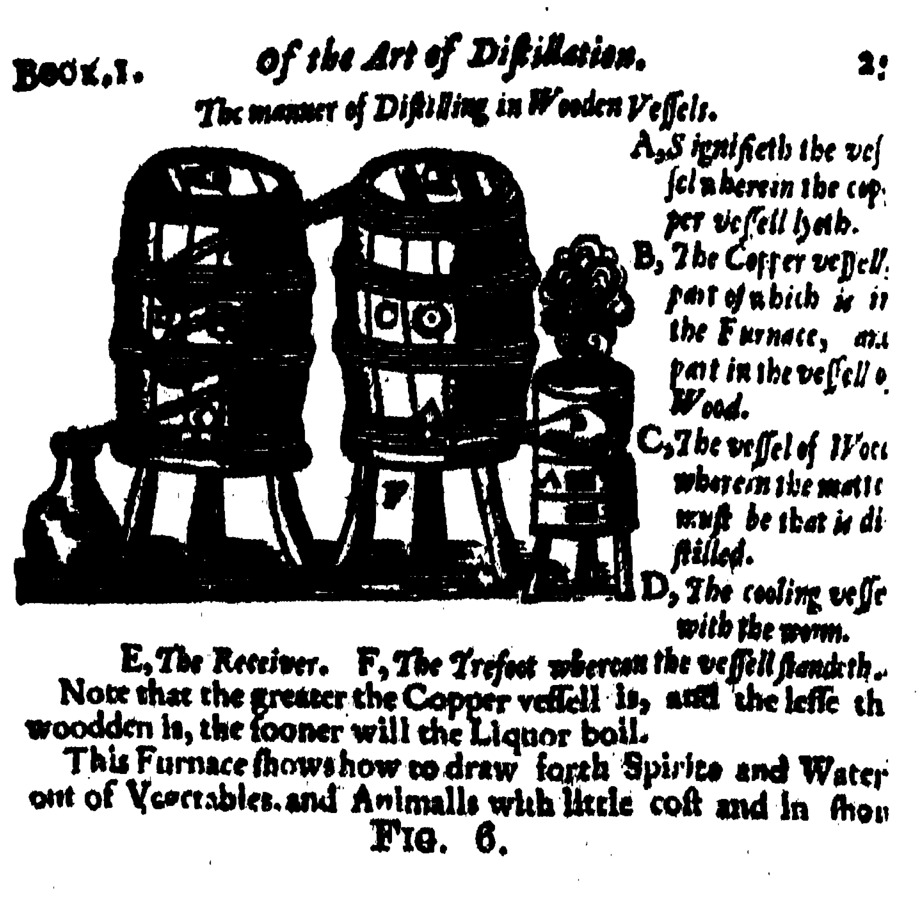


FIG. 6.

contains the water solution while the barrel on the left contains merely water to condense the vapors inside the condensing coil shown.

A fractional condenser which has been so common in oil-refining work is nicely illustrated in Figure 7. In this case,

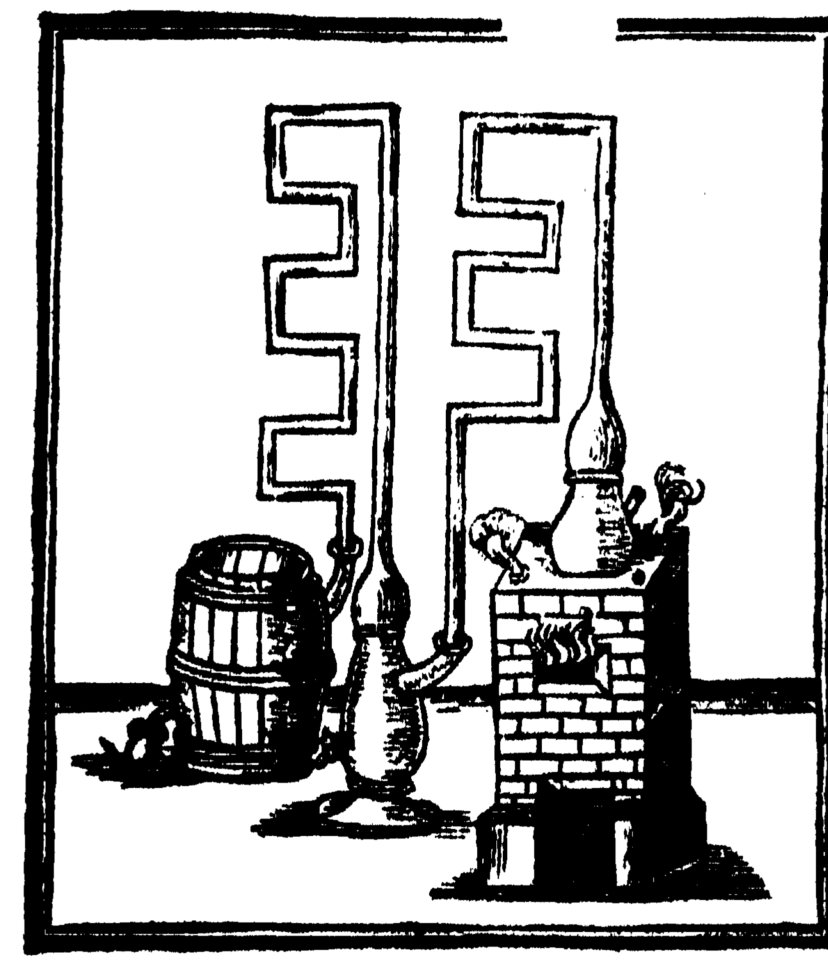


FIG. 7.

air condensers are used with a final water condenser. Three products are formed, one, the residue in the still on the right; another, an intermediate product in the vessel in the middle, and lastly, a very low boiling product coming from the condenser on the extreme left.

A very interesting case of multiple distillation or what corresponds somewhat to our modern fractionating column with its various plates is shown in Figure 8. In our modern columns

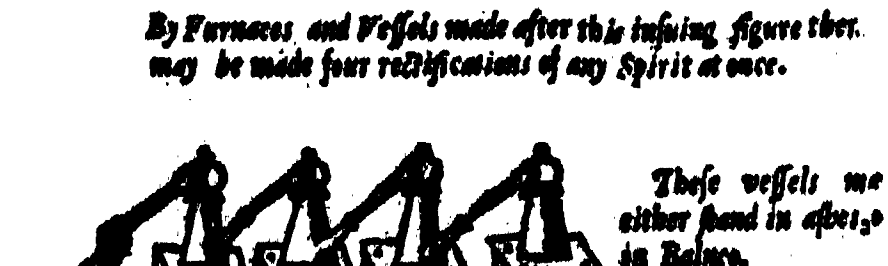
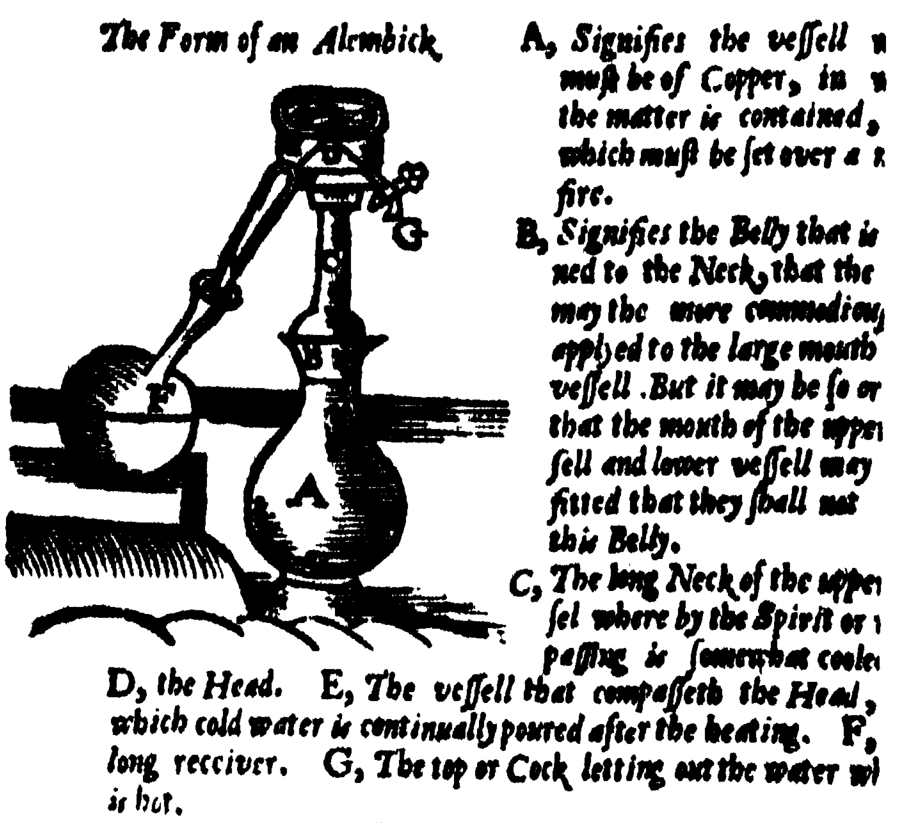


FIG. 8.

the vapor passing from one plate to another supplies the heat necessary to keep the liquid boiling on every plate.

In this case Dr. French has used a fire under each vessel or plate in order to supply the necessary heat. It should be specially noted that each vessel has its own still head or reflux condenser.

We finally come to a clear-cut example of reflux condensation together with a utilization of a column. This is shown in Figure 9. Dr. French uses


The Form of an Alembick

A, Signifies the vessell w... must be of Copper, in w... the matter is contained, which must be set over a ... fire.

B, Signifies the Belly that is ... ned to the Neck, that the ... may the more commodiou... applyed to the large mouth vessell. But it may be so or... that the mouth of the upper ... sell and lower vessell may ... fitted that they shall not ... this Belly.

C, The long Neck of the upper ... sel where by the Spirit or ... passing is somewhat coole...

D, the Head. E, The vessell that compasseth the Head, ... which cold water is continually poured after the heating. F, ... long receiver. G, The top or Cock letting out the water wh... is hot.

Fig. 9.

water as his condensing medium around the distilling head shown. He points out that the water must be continually poured in and allowed to drain through the stop-cock as indicated in order to get the proper condensation or reflux. There seems to be no doubt whatever that Dr. French understood perfectly the value and necessity for a reflux condenser in ordinary fractionation.

Before going back still further in our search for the original reflux condenser, attention should be called to Dr. French's invention shown in Figure 10.

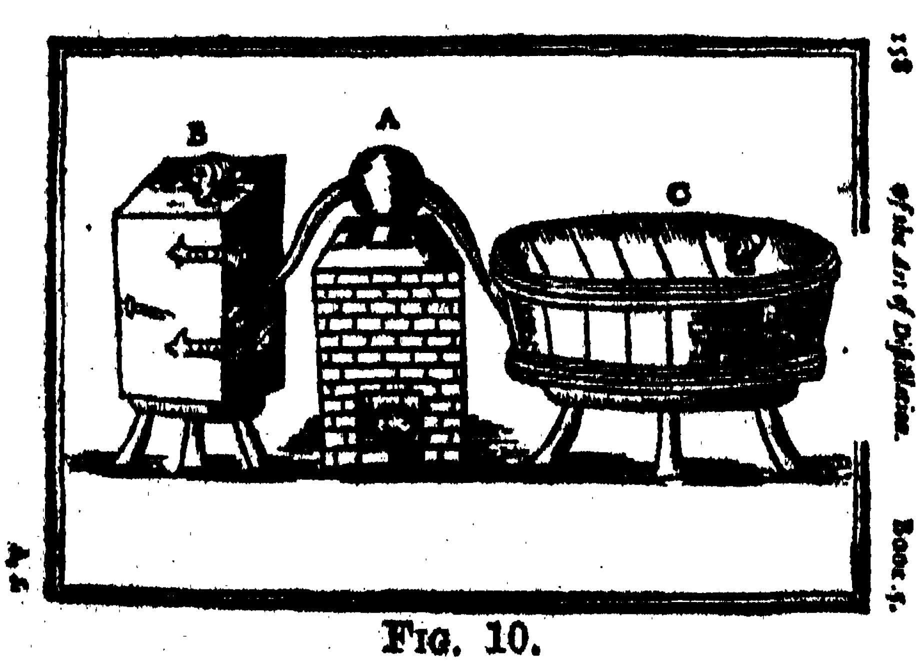


Fig. 10.

This is merely a steam distilling outfit and it might be termed the original Turkish bath. The patient on the right is not able to stand up so he is reclining in a bathtub, whereas the patient on the left is more vigorous and maintains an upright position in a steam box.

It was the author's opinion that he had traced the reflux condenser back to approximately the date of its origin. He was, therefore, very much surprized to read in an article[1] that Phillipo Ulstadio in 1525 had written a book in which the cut shown in Figure 11 appeared.


Fig. 11.

The column in the center contains cold water. The long neck of the flask passes back and forth through this column and finally to the receiver shown at the top. Unquestionably, this scheme will produce a considerable quantity of reflux, and what is even more effective from the fractionation standpoint, the reflux will pass a great distance before it reaches the still at the bottom, thus permitting a much better contact with the vapors than otherwise would be possible. It is also interesting

[1] "The Distillation of Petroleum for the Manufacture of Lubricating Oils," by William F. Parrish in the *Journal of the Franklin Institute,* 203: 781, 1927.

to note that Dr. Ulstadio in this same book entitled "Secrets of Nature" showed an excellent steam-bath reproduced in Figure 12. It should be noted

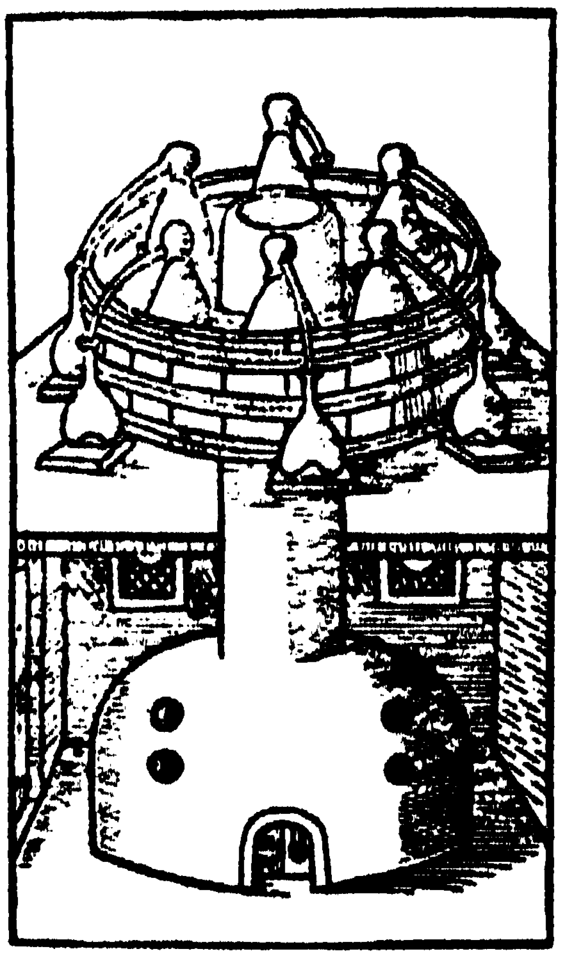


FIG. 12.

again that the distilling heads shown in this illustration act as air condensers and, therefore, provide some reflux.

In the article mentioned before[1] is still another illustration (Figure 13), taken from Dr. Herman Brunswich's book on distillation which appeared in 1500.

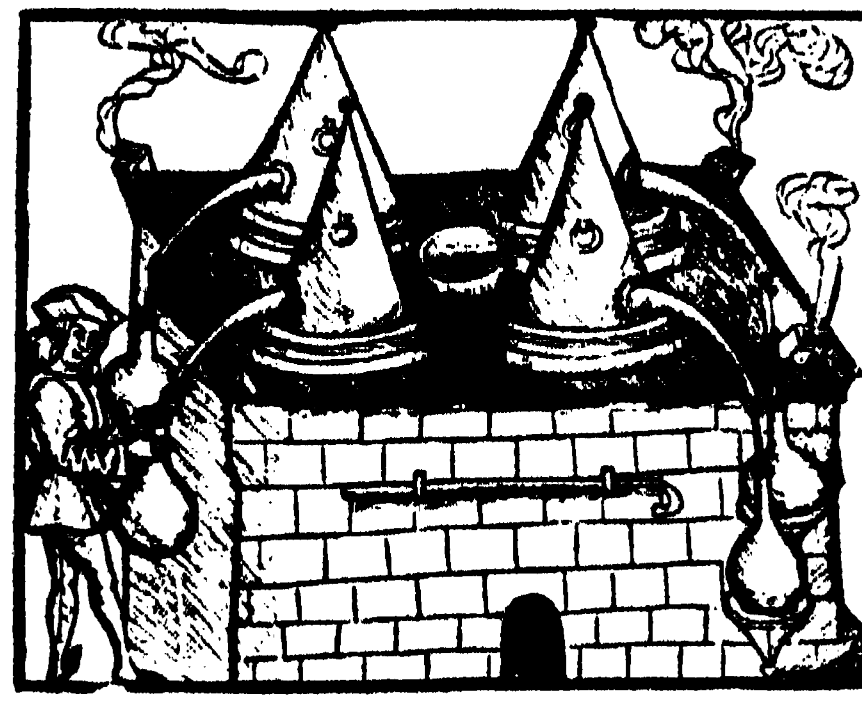


FIG. 13.

Here again we notice that the air condensers on the still heads serve as air reflux condensers.

In conclusion, the author's opinion is, the principles of fractionation and distillation used in our modern industries were probably discovered by Noah. It has been recorded that the home brew made by this distinguished gentleman was extremely potent and in all probability rectification was absolutely necessary. It can be truthfully said that though there is no particular evidence to substantiate this statement, there is no particular evidence against it and the probabilities are in its favor.

THE PROGRESS OF SCIENCE

EINSTEIN AND AMERICA

THE prominence given in our daily newspapers to Einstein's recent communication to the Berlin Academy testifies beyond question to a keen interest on the part of the general public. It is easy to ridicule this interest, and it is easy to overestimate its significance. It is not so easy to strike the balance between these opposing views of the phenomenon, and I shall not attempt to do so; but some reflections that it suggests may not be amiss.

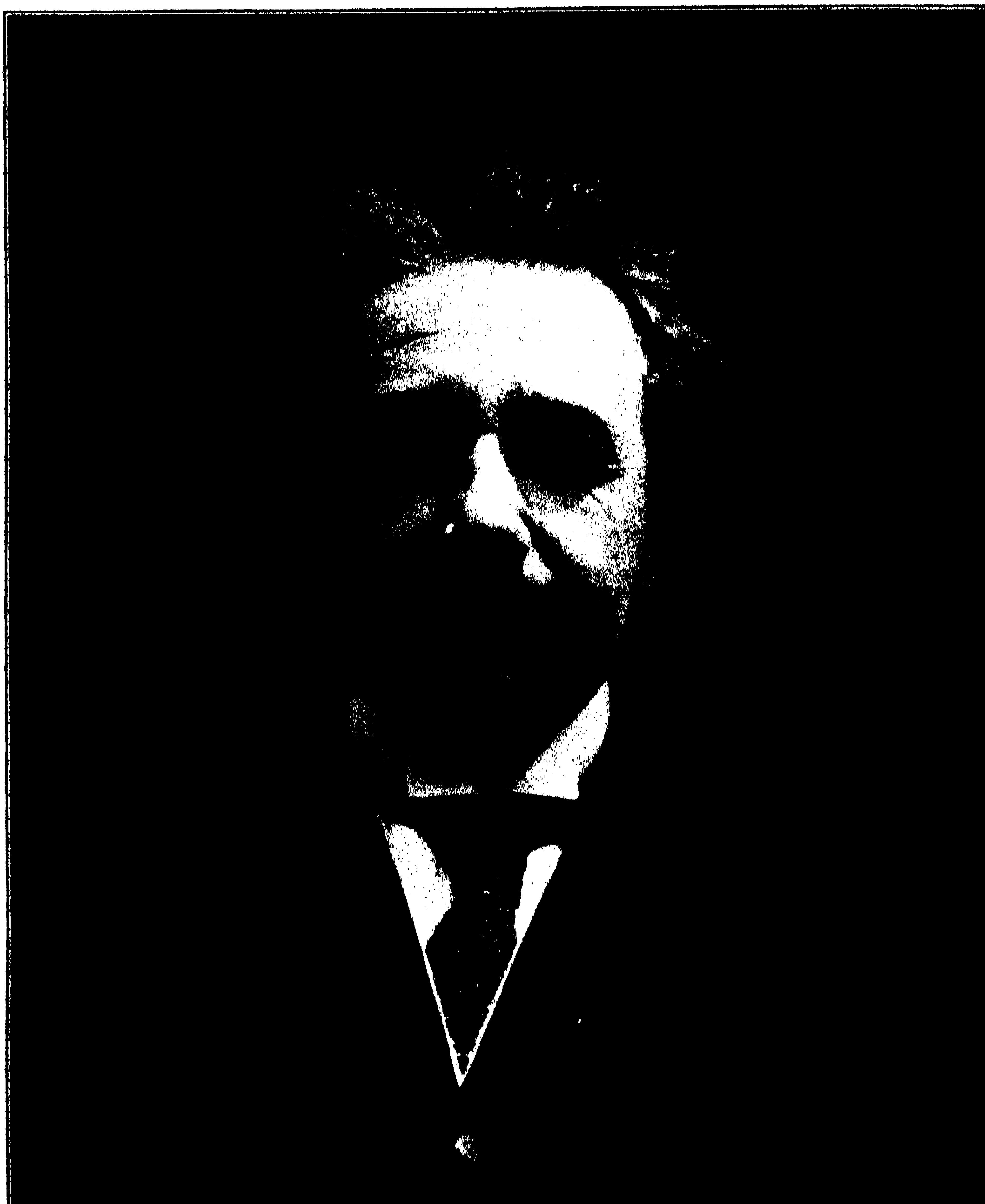
The two most remarkable examples of newspaper enterprise in connection with the Einstein paper were furnished by the New York *Herald Tribune* and the New York *Times*. The *Herald Tribune* published a complete reproduction of the paper (in English), the complicated formulas being cabled by a specially contrived method. The *Times* obtained from Einstein an article expressly written by him for the purpose, and cabled to that newspaper.

The article in the *Times* was a statement, "as simple as the subject would allow," of the nature and antecedents of the great theory which has so profoundly affected scientific thought in the past two decades. The number of those who fully grasped it was of course small. But of those who could not fully grasp it there must have been a not inconsiderable fraction to whom it gave some conception of the change wrought by Einstein and his contemporaries in our notions of the fundamentals of physics, and some realization of the depth and sweep and difficulty of the achievements of their illustrious predecessors. To do so much as this, to do it without producing in the reader any illusory feeling of having obtained more than this, and yet to do it in such a way as to thrill him with the sense of real contact with a great mind and with a stupendous theme, is a wonderful achievement.

The ferment which has been stirred up by the theory of relativity presents some interesting points both of resemblance and of contrast with the ferment which was so prominent a feature of the intellectual situation about half a century ago. Two great scientific doctrines were then in the foreground of general thought—the doctrine of evolution and that of the conservation of energy. The latter doctrine had long passed the stage of novelty in scientific circles, and even *The Origin of Species* was in its second decade; but both of the doctrines had the zest of novelty to the educated public in general, and in each of them that public found the inspiring quality that goes with the sudden illumination of a vast field of knowledge.

The universal interest with which the Einstein theory and other recent developments in physics have been received is a manifestation of the same feeling. However little one may understand either of the theory of relativity or of the consequences, scientific and philosophical, which have been derived from it, there can be no mistaking its character as one of the great landmarks in the history of thought. But nearly everybody has sense enough to know that it is hopeless for him to get more than the vaguest notion of what it is all about; in this respect there is a great contrast between the present situation and that of the early seventies of the last century.

The origin of species by means of natural selection and the doctrine of the conservation of energy were of primitive



—*Underwood and Underwood*

PROFESSOR ALBERT EINSTEIN

A PHOTOGRAPH TAKEN AT THE TIME OF PROFESSOR EINSTEIN'S VISIT TO THE UNITED STATES IN 1921.

—Herbert Photo

PROFESSOR AND MRS. ALBERT EINSTEIN

simplicity in comparison with the Einstein theories and the theory of quanta; and ordinary people were justified in feeling that they had got hold of the essentials of those two doctrines. Nevertheless it happened only too often that even the essentials of those doctrines had not been thoroughly grasped by persons who thought that they had mastered them; and accordingly many grotesque and not a few harmful inferences were drawn from them. It seems hardly credible, but nevertheless it is a fact, that a distinguished professor of sociology, a man of high intellectual endowments, deliberately asserted, in a printed book, that since popular elections are not a source of energy, they can not cause anything at all. It is one of the comforts of the Einstein situation that the profundity and difficulty of the theory are so great, and are acknowledged to be so great, that nobody will be in danger of committing in its name absurdities of any such kind.

A different kind of popular error might naturally have been expected to gain currency but does not seem to have done so. That the general interest in these startling advances springs in the main from normal intellectual curiosity, and not from a childish delight in novelties, is best evidenced by the almost total absence of light-headed observations upon the dethronement of Newton and Euclid. That the science of to-day has not discarded the science of yesterday, but has absorbed and developed it; that in its transformed state it retains, and will continue fruitfully to use, nearly all that had been acquired and established in the course of ages—these things seem to be fairly well understood by the general public. And I venture to say that this sobriety and sanity of thought is in some degree attributable to the exemplary modesty which Einstein himself has shown throughout his career. Nothing could be finer than the serene impartiality of his statements, from time to time, as to the degree in which his theories required confirmation or had received it; unless it be the total absence of self-assertion in his communications to the public, of which the *Times* article above spoken of is an instance. "Don't mind if people call you a braggart," said Don Marquis in one of his best witticisms; "leave modesty to those who have something to be modest about." Einstein certainly has something to be modest about.

FABIAN FRANKLIN

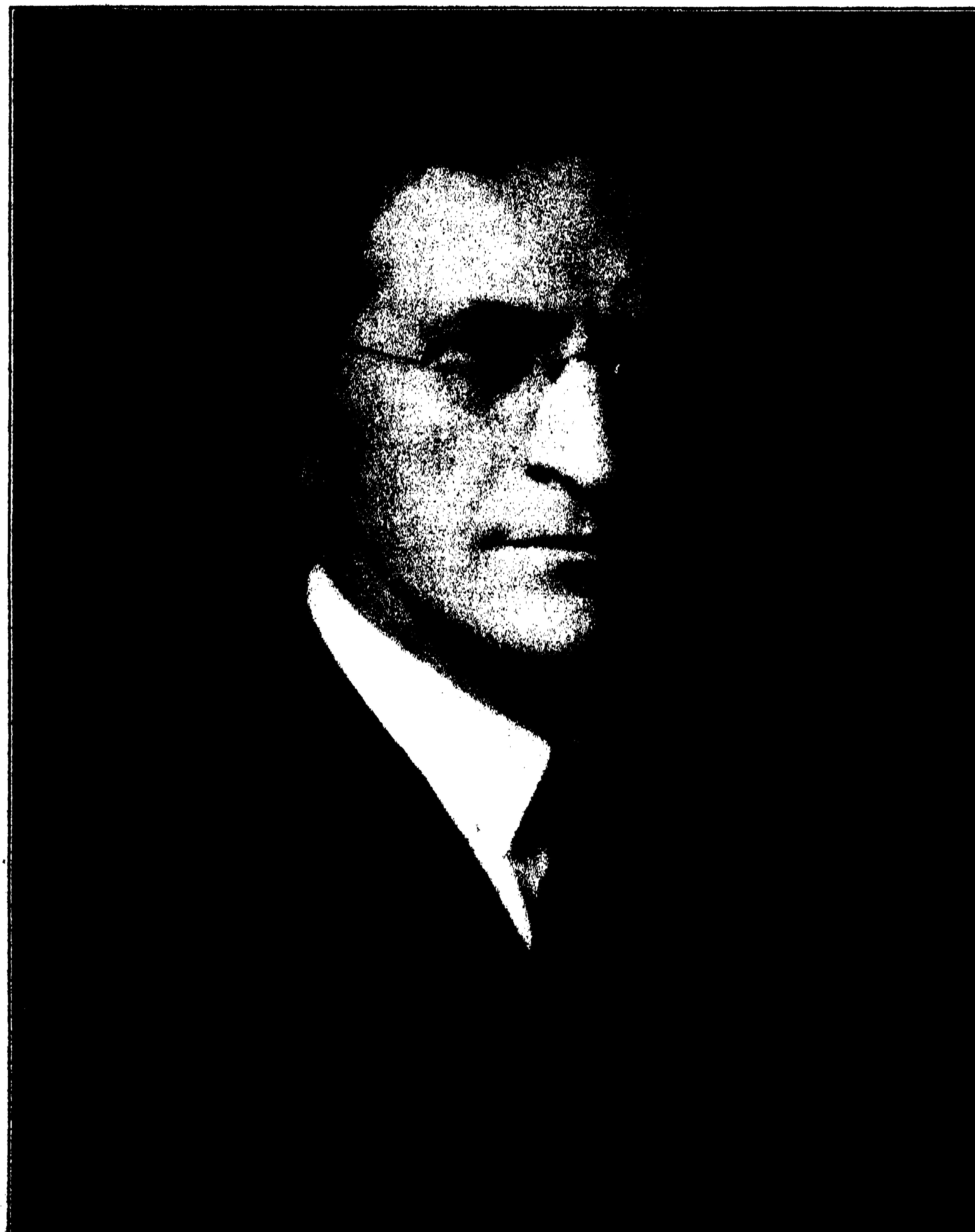
JOSEPH GOLDBERGER

DR. JOSEPH GOLDBERGER, of the Federal Hygienic Laboratory, distinguished for his work in pellagra, has died from a form of anemia which may have resulted indirectly from his experimental work.

He contracted typhus fever, dengue and yellow fever while studying these diseases. Both he and his wife subjected themselves to experiments with pellagra in order to test the manner by which this disease may be contracted.

He was born in Austria-Hungary in 1874, coming to this country with his parents at the age of six. His first work was the examination of immigrants at Ellis Island, and routine duty at other immigration stations and U. S. consulates. However, his unusual qualifications for research work were soon recognized and in 1904 he became attached to the Hygienic Laboratory at Washington, where he continued to work until his untimely death.

Dr. Goldberger's greatest contribution to science and to humanity was the discovery of the cause, cure and prevention of pellagra. For hundreds of



JOSEPH GOLDBERGER

years this disease had been known in Europe, but it was not identified in the United States until 1907. One of the dramatic chapters in the history of public health is the story of his trips through the south taken to investigate orphanages, asylums and prisons where pellagra so often prevailed. He observed the remarkable fact that in orphanages it was only the children from six to twelve years, who were not given milk and were too small to earn meat by doing chores, who were afflicted with the red rash and sore mouths and jangling nerves of pellagara.

Lack of fresh proteins in the diet causes pellagra. Adding milk and fresh meat to the diet will cure or prevent the disease. Dr. Goldberger was convinced of this in 1915, but it took him years to prove it to a skeptical world. First he produced pellagra in eleven convict volunteers, through feeding them a diet lacking in fresh meat and milk but otherwise substantial. Many times he risked his life and that of his loyal wife and fellow-workers, to show that pellagra is not caused by any germ in the blood or skin or intestinal discharges. This brave party allowed themselves to be injected with blood and with material from the sore skins of dying pellagrins. Dr. Goldberger himself and some of the others swallowed pellets made of the intestinal discharges. The experimenters did not contract pellagra, and it was thus established that it was not a germ disease.

Dr. Goldberger realized that fresh meat and milk for the poverty-stricken inhabitants of the south were prohibitive; and he finally discovered the pellagra-preventive substance in yeast. A small amount of yeast, either fresh or dried, will cure and prevent pellagra.

In a recent report Dr. Goldberger wrote that canned salmon, egg yolk and canned tomato were found to contain some of the pellagra-preventive substance, but that it probably requires nearly two pounds of tomatoes, equivalent to about one quart of canned tomato juice, to produce about the same preventive effect as a quart of buttermilk or as about half a pound of lean meat, or as one ounce of powdered yeast.

Other animals get a disease almost identical with pellagra. Especially notable is blacktongue disease of dogs. The identity of these diseases and human pellagra was discovered by Dr. Goldberger. Immediately he put this fact to work in searching for other foods that would prevent and cure pellagra. This is the task upon which he was working when taken ill two months ago.

The pellagra research was not Dr. Goldberger's only contribution to science. He discovered the cause and methods of transmission of the straw mite disease. He worked on yellow fever, dengue fever and diphtheria. He and a colleague were able to transmit measles to lower animals and thus throw light on the period of incubation and infectivity of the disease. He assisted with the influenza studies in which a few attempts to transmit the disease from person to person were made.

Important were his studies of typhus fever, which he contracted during his work with it. He was able to show that the typhus fever of Mexico was the same as Brill's disease, a mild form of typhus known to be prevalent in New York and certain other places in the United States for many years.

A bill has been introduced into the United States Senate to provide a pension of $150 a month for Mrs. Goldberger. Here is a chance for a republic to show recognition and justice to a public officer who gave his all without thought of gain. It would be helpful if the readers of THE SCIENTIFIC MONTHLY would write to members of the Congress that they may know, endorsing the bill and asking their interest.

THE NORTH PACIFIC INDIAN HALL

THE AMERICAN MUSEUM OF NATURAL HISTORY

At the recent meetings of the American Association for the Advancement of Science many people became more fully acquainted with the American Museum of Natural History, which was so important a factor in the success of the convocation. The development of the institution has kept abreast with the progress of science and it may be of interest to give here some account of this great museum and its work.

The founders of the American Museum of Natural History, in the articles of incorporation in 1869, announced their intention of "establishing a museum and library of natural history, of encouraging and developing natural science, of advancing the general knowledge of kindred subjects, and to that end of furnishing popular instruction."

Commencing with a few collections which were exhibited for a number of years in the old arsenal building, which is still in evidence in Central Park, the founders, with great forethought, planned an institution which has now become internationally known as a distributor of the latest information in the sciences pertaining to natural history and its kindred subjects.

When the plans had progressed sufficiently, the trustees called upon Calvert Vaux and J. Wrey Moulder to design a series of buildings which would cover the entire area of Manhattan Square, and in 1874 the corner-stone of the present building was laid by President Grant. For many years following, Manhattan Square was considered to be in a remote and isolated section of the city, but with the passing of years it has become the center, not alone of the populated area, but as well of the scientific and educational activities of the Borough of Manhattan.

Through its articles of incorporation the museum operates under the control of a self-perpetuating board of trustees, which board has the entire direction of all the activities of the museum, as

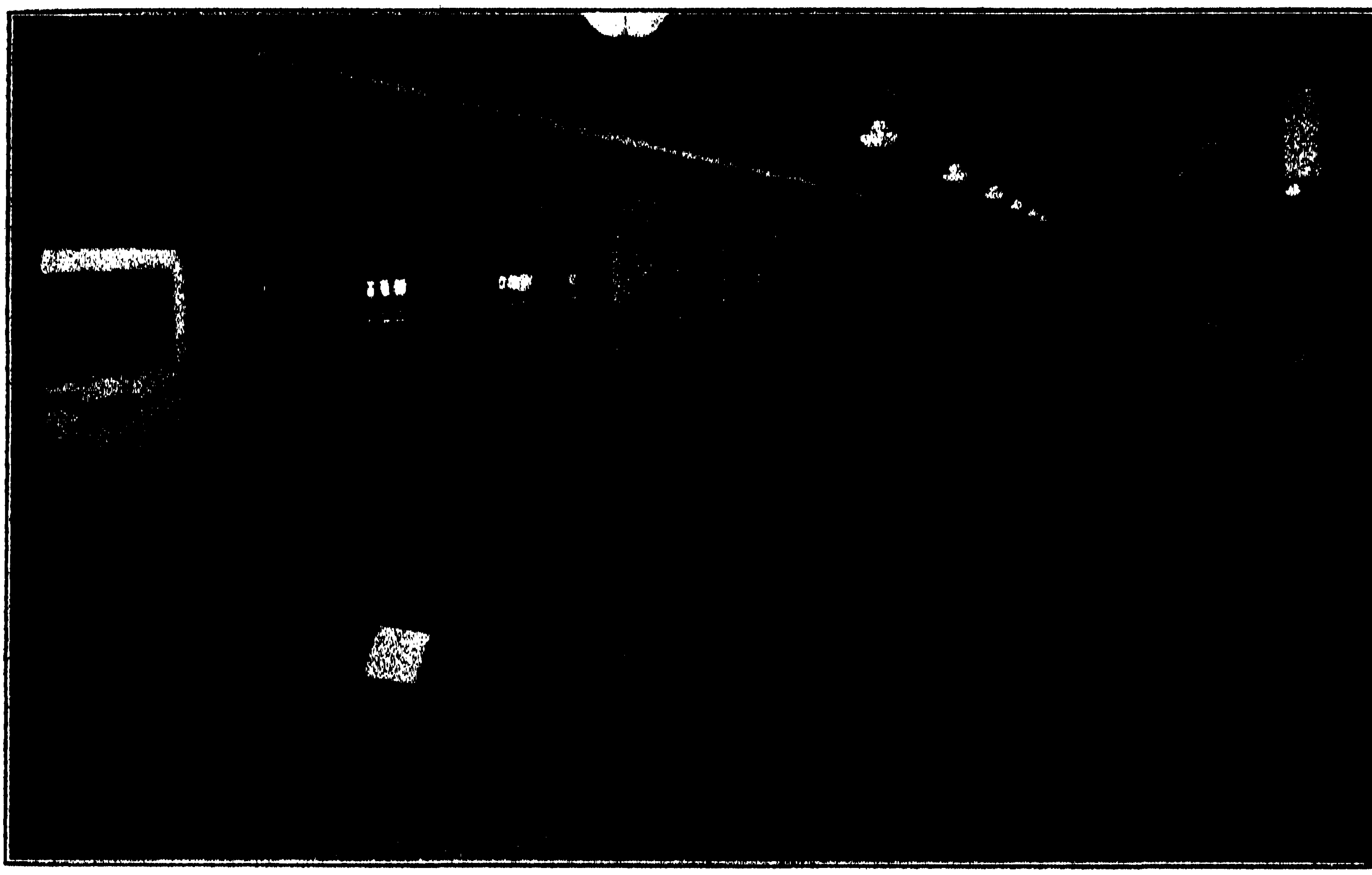
THE DINOSAUR HALL

well as the guardianship of its halls and exhibits. The collections in the exhibition halls and study rooms are the gifts of the trustees, members and other friends and supporters of the institution, as are also the funds which enable the trustees to purchase specimens, to carry on explorations, publish scientific papers and enlarge the library.

In obtaining specimens for exhibition, the first thought of the trustees has been to secure a representative series, first from the United States, then from North America and, lastly, from all other parts of the world. When preparing material for exhibition, great thought and care are expended upon specimens for groups in order to give the visitor every environmental effect without unduly stressing it. From duplicate material, study collections have been set up which rank among the first in the world. The scientific workers endeavor to bring out, not alone the anatomical features which characterize individual specimens, but as well the distribution of the species. To do all this, a vast corps of workers is employed, numbering at present, from the highest to the lowest, four hundred and fifty employees.

In recent years the whole science of taxidermy has been revolutionized, chiefly through the intelligent effort and artistic ability of the late Carl E. Akeley, a master in his craft. The old system of stuffing animals with ragee and straw has been replaced by one which begins in the field where photographs are made, if possible, of the animal while alive. These are of great value in posing the mounted groups. Immediately after the animal is shot, measurements are made, then it is skinned and the hide prepared and packed to be shipped, as well as the skeleton.

In the mounting of animals at the museum, a rough armature is made on which a life-sized clay model is shaped just like a clay model made for casting in bronze, except that to facilitate ac-



THE NEW REPTILE HALL

curacy the skull and leg bones of the animal are used. The model is checked by measurements made of the dead animal in the field, by photographs and frequently by anatomical casts made in the field. The final result is a model, not only of the species, but of the actual animal to be used. For temporary purposes a skin could be mounted on the clay model, but an animal so mounted would deteriorate. For permanent work it was necessary to devise some light, durable substance, which would not be affected by moisture, to take the place of the clay mannikin. The material finally decided upon was papier-mâché. A mannikin of this, reinforced with wire cloth and coated with shellac, was found to be tough, strong, durable and impervious to moisture. It is impossible to model papier-mâché with the hands as one moulds clay, so the problem resolved itself into making a plaster mould of the clay model and then using that to build the papier-mâché mannikin. To make a bronze in a mould, one pours the melted metal into the mould and when it has cooled, the mould is removed. But papier-mâché reenforced with wire cloth can not be poured, and if it is put into a plaster of paris mould it will stick. The solution of the difficulty was found by taking the plaster moulds of the clay model and coating them on the inside with glue. On this glue a sheet of muslin is laid and worked carefully into every undulation of the mould. On this are placed thin layers of papier-mâché with the wire cloth reenforcement likewise worked into the mould. Every layer of the papier-mâché composition is carefully covered with a coating of shellac so that each layer, as well as the whole, is entirely impervious to water. For animals the size of a deer, two layers of reenforced composition give strength enough. When the final coat of shellac is well dried, the whole thing is immersed in water. It affects nothing but the thin coating of glue between the mould and the muslin. That melted, the muslin-covered, reenforced papier-mâché sections of the mannikin come

out of the plaster mould clean and perfect replicas of the original clay model. Of the animal, only the horns, hoofs and skull are used.

An artist accompanies an expedition to paint the background, for it is as necessary that the setting be correct as that the animals be properly and artistically posed. Also the material for the foreground has to be collected—trees, bushes, foliage and all that would go to make up a native scene. In the case of the coral reef group now under preparation at the museum, forty tons of coral were shipped up from the Bahamas.

A complete revolution has also been brought about in the matter of mounting amphibians and reptiles at the museum. Formerly such specimens were cast in wax and accurately colored by skilled artists. These had their drawbacks in that they were very fragile and chiefly because it was a very expensive process to make them "look alive." For the larger specimens, of course, the process of skinning can be employed and then mounting the skin over a mannikin. This is useful for all but the softer-bodied specimens. A method was long sought for that should retain the appearance of "fleshiness" in the object. This was finally found in a method of paraffin infiltration. It is not wholly new, having been used by Professor Hochstetter, of Vienna, for some time, and it has been in use in the American Museum laboratories for certain kinds of work for some years. It was found possible to infiltrate the bodies of reptiles and amphibians so as to retain not only their original forms but also the body colors. Even the internal organs, heart, liver and lungs, are infiltrated so that the creature is perfectly natural in appearance. The eyes alone did not take the treatment wholly successfully, so in amphibians they were replaced with pin heads and in reptiles were touched up with a little color. There is not space in the present article to explain the interesting process in detail, but the successful results may be seen in the Reptile Hall of the museum.

While the scientific work has been recorded, no mention has been made of the contact by the museum with the schools. This work has grown to such proportions that a special building, known as the School Service Building, has recently been erected by the city authorities, who recognized the importance of the museum in educational circles. From this comprehensive storehouse are distributed nature study collections, slides and films, without charge, to the city schools. This material is sent out in such quantities that it is necessary to employ five automobiles to make the distributions, and for the past year it is recorded that through these collections the museum made contacts with over ten millions of children. Museum aid is sought by teachers for the purpose of giving visual instruction on the resources of nature. By such means children are able to see life in its beginnings and life in the past, from the tiny animalcule to the huge brontosaurus.

In brief, the American Museum as now directed has for its chief objects, keeping the public in touch with the progress of science, and demonstrating the importance of research. Its halls are daily thronged with visitors who are impressed with its many activities and who realize that in this, the greatest schoolhouse in the world, may be found faithfully represented nature's lessons to the race.

George N. Pindar,
Chairman, Committee on Public Information

THE SCIENTIFIC MONTHLY

APRIL, 1929

WHAT IS LIGHT?[1]

By Dr. ARTHUR H. COMPTON

PROFESSOR OF PHYSICS AT THE UNIVERSITY OF CHICAGO, AND RECIPIENT OF THE NOBEL PRIZE IN PHYSICS IN 1927.

FROM the time that the ancient Greeks told each other about the shafts of light shot by Apollo, men have concerned themselves with what light is. Together with its sister problem, the nature of matter, this question presents the fascination of a fundamental mystery. During the last generation a rich mine of new information regarding light has been worked, and the remarkable discoveries that have thus appeared have seemed to make the subject a suitable one to present before the Society of Sigma Xi. Yet in spite of this new information light remains as perhaps the darkest of our physical problems, and as such may well be reviewed before the Physics section of the American Association.

As long ago as the seventeenth century, Newton defended the view that light consists of streams of little particles, shot with tremendous speed from a candle or the sun or any other source of light. At the dawn of the nineteenth century, however, experiments were performed which were thought to give positive evidence that light consists of waves. Maxwell interpreted them as electromagnetic waves, and in such terms we have ever since been explaining light rays, X-rays and radio rays. We have measured the length of the waves, their frequency and other characteristics, and have felt that we know them intimately. Very recently, however, a group of electrical effects of light has been discovered for which the idea of light waves suggests no explanation, but whose interpretation is obvious according to a modified form of Newton's old theory of light projectiles.

REVIEW OF THE VARIOUS ELECTROMAGNETIC RADIATIONS

When the physicist speaks of light he thinks not only of those radiations which affect the eye. He refers rather to a wide range of radiations, similar to light in essential nature, but differing in the quality described variously by the terms color, wave-length or frequency.

At one end of this series of radiations are the wireless, or radio rays, with which in recent years we have become so familiar. There is an important point regarding these rays which I should like to call to your attention. When one strikes the strings of a mandolin, they are set into vibration, and produce up in the surrounding air the waves which affect our ears and cause the sensation of sound. Investigation shows that the sound waves in the air vibrate with the

[1] Address given jointly as the annual Sigma Xi address and as the retiring vice-presidential address of the physics section of the American Association for the Advancement of Science. The address was presented at a general session of the American Association on the evening of December 28.

same frequency—the same number of times per second—as do the strings on the mandolin. In precisely the same way, when electrically charged condensers are discharged, an oscillation of the electric charge is set up which gives rise to electric waves just as the vibrating string produced sound waves. These electric waves are caught by an electric ear at the rear of the room, and are there transformed through a loud speaker into the noise which offends your tone-conscious ears.

The emitted electric waves have the same frequency as the oscillating source. Though visible light is known to be essentially the same kind of thing as these electric waves, we have long sought in vain for any oscillator which would emit light waves having the same frequency as that of the oscillating source. It was only when Heisenberg introduced a new kind of mechanics, differing radically from the classical ideas of Newton, that we found that the atom vibrates with certain "overtones" whose frequency is that of the light waves which come from it. This is one of the serious difficulties with the wave conception of light which could only be solved by a fundamental change in our ideas regarding how things work.

Measured in terms of the length of a wave, electric waves extend from many miles in length down through the radio waves of say 300 meters, to the very short waves resulting from tiny sparks, which may be no more than a tenth of a millimeter in length. These rays overlap in wave-length the longest heat waves radiated by hot bodies, and may be detected and measured by the same instruments. A familiar source of such heat rays is the reflector type of electric heater, the kind that warms one side of us in a chilly room. The greater part of these heat rays are intermediate in wave-length between the shortest electric waves and visible light. Such a heater, however, glows a dull red, showing how its rays extend into the visible region.

Ordinary visible light is well represented by the radiation from a carbon arc. I shall pass its rays through a lens and prism, and project them onto this screen. We see how it is made up of rays of many colors, from red to violet, which the prism has separated from each other. Beyond the red end of the spectrum lie the heat rays. Indeed if we should place a radiometer just beyond the red end of the spectrum, we should find it strongly affected by the heat rays from the arc. The question arises, are there similar radiations beyond the violet which we are unable to see?

In order to answer this question, let me bring up a fluorescent screen of platinum barium cyanide. Notice the brilliant green glow extending far beyond the violet light on the ordinary screen. Evidently our failure to see light in this region is not because there is no light, but because our eyes are insensitive to rays of this type. The fluorescent screen changes their color so that we can see them. These are the ultra-violet rays, of which we have heard so much recently in connection with summer sunshine and prevention of rickets.

As one goes farther into the ultra-violet the rays become rapidly absorbed by air, and can be studied only in a vacuum. But at still shorter wave-lengths the rays are again less readily absorbed as we approach the region of X-rays. A high tension transformer shoots the electrons at high speed from the hot wire cathode against the tungsten target and these X-rays are emitted (Fig. 1). It is like shooting a rapid fire gun at a steel plate. The bullets represent the electrons shot from the cathode, and the noise resulting when the bullets bang against the plate represents the X-rays.

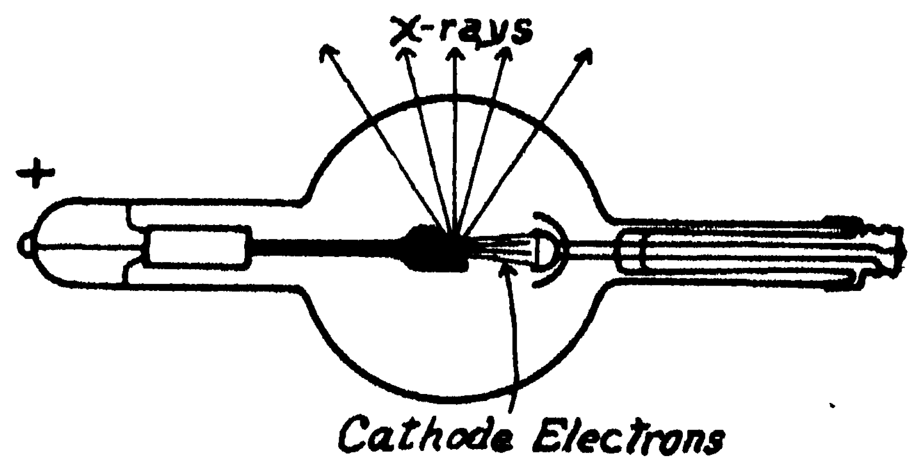


FIG. 1. COOLIDGE X-RAY TUBE
ELECTRONS SHOT FROM THE CATHODE AGAINST THE TARGET PRODUCE THERE X-RAYS, WHICH ARE LIGHT OF VERY SHORT WAVE-LENGTH.

Just as in the case of ultra-violet light, these X-rays do not affect our eyes. Their existence can, however, be shown by placing in their path the same screen which we used to detect the ultra-violet rays. Notice how it lights up when I apply the voltage from the transformer. That these rays are of the same nature as light is shown by the fact that we have found it possible to reflect and refract them, to polarize and diffract them. They are indeed light of ten thousand times shorter wave-length.

One of the most important properties of X-rays is their ability to ionize air and make it electrically conducting. Let me show this by the following experiment. You see projected on the screen the gold leaf of an electroscope. Notice, when I turn on the X-rays, how quickly the leaf falls, showing that the electroscope has lost its charge. This is due to the breaking up by the X-rays of the oxygen and nitrogen atoms in the air. Precisely the same thing happens to the atoms in one's body when in the path of X-rays. This it is which makes possible X-ray burns and X-ray therapy.

Such ionization can also be produced by the gamma rays from radium. Let us charge the electroscope again. This time instead of turning on the X-rays, we shall bring up a small tube containing a milligram of radium. Again the leaf falls as the electroscope loses its charge. These rays are much less intense than the X-rays, as is shown by the slowness with which the leaf drops. They are, on the other hand, much more penetrating. Whereas X-rays may be half absorbed in an inch of water, it takes a foot of water to absorb half of these gamma rays from radium, corresponding to the much shorter wave-length of the radioactive rays.

But the end is not yet. There exists a kind of highly penetrating radiation which is especially prominent at high altitudes, and is supposed to come from some source outside the earth. These *cosmic rays*, as they are called, will penetrate ten or twenty feet of water before they are half absorbed. Unfortunately I can not show them to you here, for it would take all night for such rays to make an appreciable effect on our electroscope.

In Fig. 2 we see graphically how these different rays are related to each other. At the extreme left I have arbitrarily started the spectrum at a wave-length of eighteen kilometers, which is the wave-length of certain transatlantic wireless signals. There is no reason why longer waves could not be produced if desired. The electric waves continue in an unbroken spectrum down to 0.1 mm, rays recently studied at Cleveland by the late Dr. Nichols and Mr. Tear. Overlapping these electric waves are the heat rays, which have been observed from about .03 cm to .000,03 cm, including the whole of the visible region. The heat rays in turn are overlapped by the ultra-violet rays, produced by electric discharges; and these reach well into the region described as X-rays. Beyond these are in turn the gamma rays and the cosmic rays. Thus over a range of wave-lengths of from 2×10^{-13} cm to 2×10^{-6} cm there is found to be a continuous spectrum of radiations, of which visible light occupies only a very narrow band.

The great breadth of this wave-length range will perhaps be better appreciated if we expand the scale until the wave of

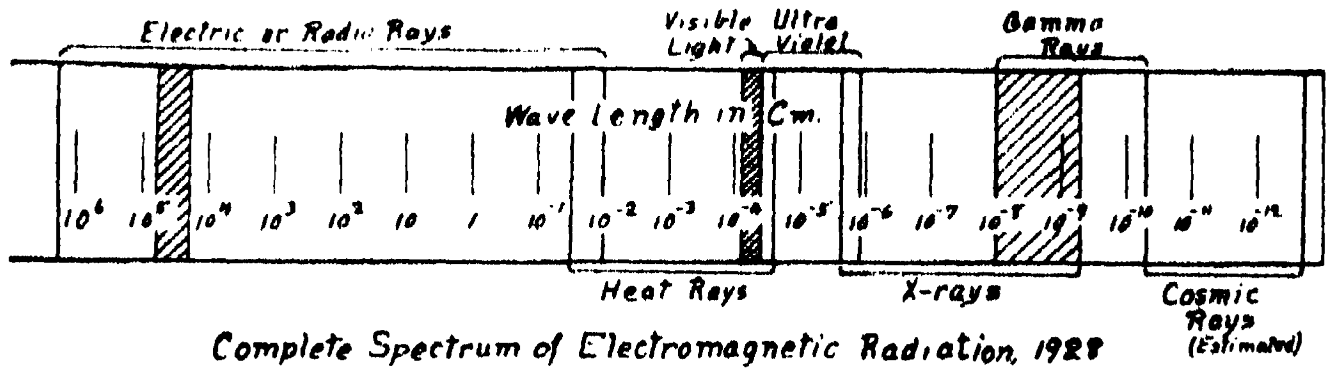


FIG. 2. COMPLETE SPECTRUM OF ELECTROMAGNETIC RADIATION

ON A LOGARITHMIC SCALE. VISIBLE LIGHT IS ONLY A SMALL BUT VERY IMPORTANT PART OF THIS SPECTRUM.

a cosmic ray has a length equal to the thickness of a post card. The longest wireless wave would on this scale extend from here to the nearest fixed star.

When the physicist speaks of light, he refers to all the radiations included in this vast range. We believe that they are all the same kind of thing, and that anything which may be said about the nature of the rays in one part of this region is equally true of the rest.

It will perhaps be profitable to pause at this point and ask ourselves what type of evidence we may hope to get regarding the nature of radiation. When men began to inquire regarding what sound is, it was possible for them to feel the vibrations of the sounding bodies in many cases, and sometimes even to feel the vibrations set up by the sound itself. The sound thus *acts as if* it were a wave motion. When later we found it possible to photograph the shadow cast by a sound wave, no one could reasonably question the existence of the waves. There seems to be no possibility of seeing or photographing a light wave or light corpuscle as we can a sound wave or a bullet in flight. If, however, light consists of waves, it should act as waves do; and if it consists of corpuscles it should act as do corpuscles. This is probably as far as we can go.

Light Consists of Waves

There are many ways in which light acts like a wave in an elastic medium. Such elastic waves move with a speed which is the same for all wave-lengths and all intensities, just as does light. Waves, like light rays, can be reflected and refracted. The polarization of light is a property characteristic of the transverse waves in an elastic solid. It is true that if one examines the constancy of the speed of light in detail, difficulties arise; for it is found that its speed is the same relative to an observer no matter how fast the observer is going. This would not be true if light were a wave in an ordinary elastic medium. Maxwell's identification of light as electromagnetic waves, however, removes this difficulty.

The crucial test for the existence of waves, however, has always been that of diffraction and interference. You have doubtless at some time amused yourselves by dropping pebbles into a pond, and watching the ripples spread out. Perhaps two pebbles fell in at once. In some places the crests of the two sets of ripples would come together and reinforce each other. Elsewhere perhaps the crests of one set of ripples would fall on the troughs of the other and both would be neutralized. Suppose we should drop a whole row of pebbles at once into the pond. The effect would be like that shown in Fig. 3.

In this figure we imagine a series of waves passing through a succession of openings in a grid. After passing through, the crests of the emerging wavelets recombine to form a new wave going straight ahead. But in addition, the wavelet just emerging from one

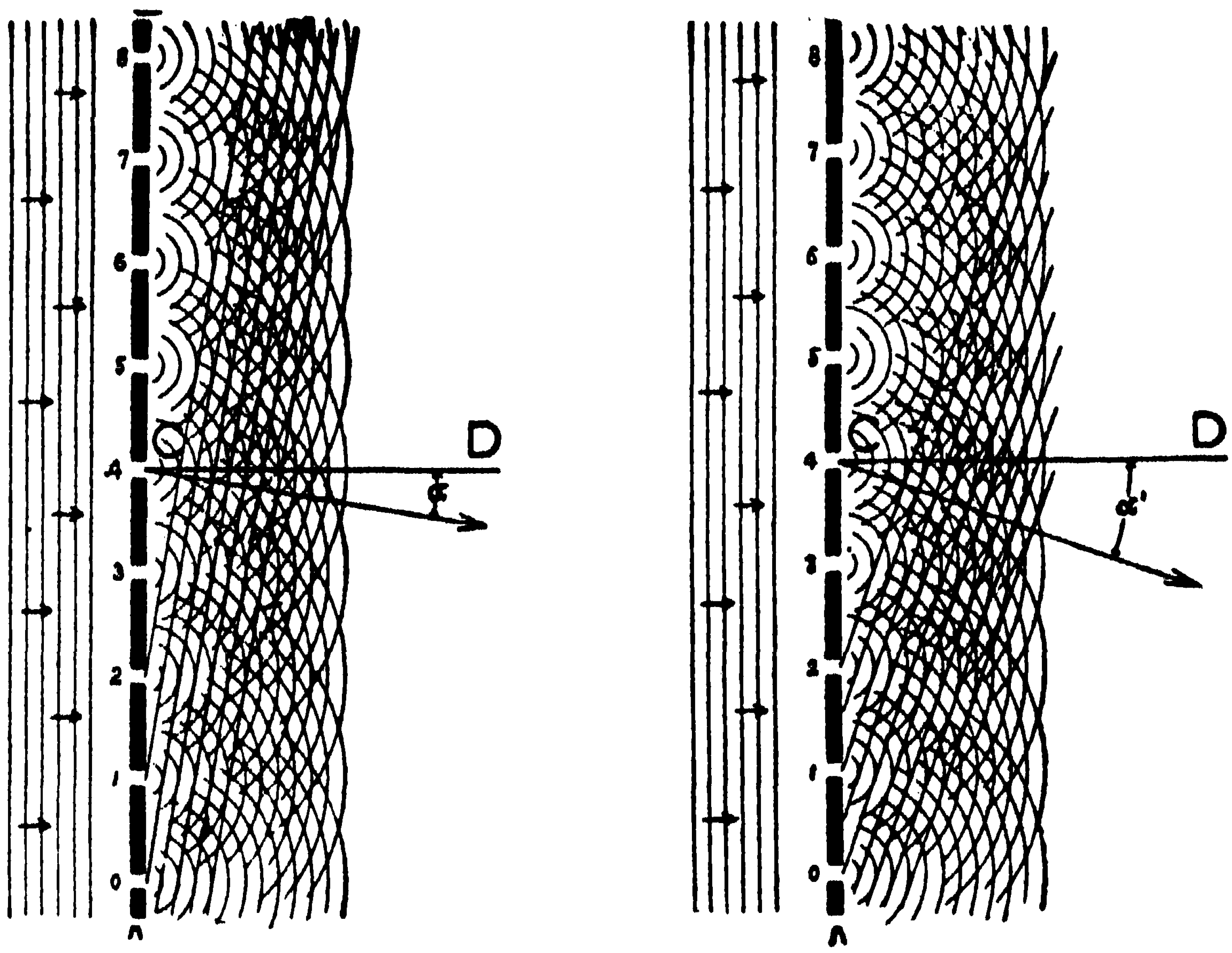


FIG. 3. DIAGRAM OF THE DIFFRACTION OF WAVES BY A GRID.

opening may combine with the first wave from the next opening, the second from the next, and so on, forming a new wave-front inclined at a definite angle to the first. The angle between these two waves, as you see from this diagram, is determined by the distance between successive waves—*i.e.*, the wave-length—and by the distance between successive openings in the grid. The figure at the right shows how the emergent wave may combine with the second wave from the adjacent opening, the fourth from the second opening, and so on, and form a wave-front propagated at a larger angle.

That such a variety of wave formation is not purely imaginary is shown in Fig. 4, which is a photograph of ripples on the surface of mercury, taken after they have passed through a comb-like grid. Notice how one group of waves combines to form a wave-front going straight ahead. But in addition, on either side of the central beam, we find two beams forming where the paths from successive openings in the grid differ by one wave-length. Out at a large angle we see even the second order of the diffracted beam.

If we were unable to see the separate waves, but knew the kind of grid through which the beam of ripples had passed, not only could we say that this is the way the beam should be split up if it consists of waves, but we could even tell what the wave-length of the ripples must be in order to give these particular angles between the diffracted beams.

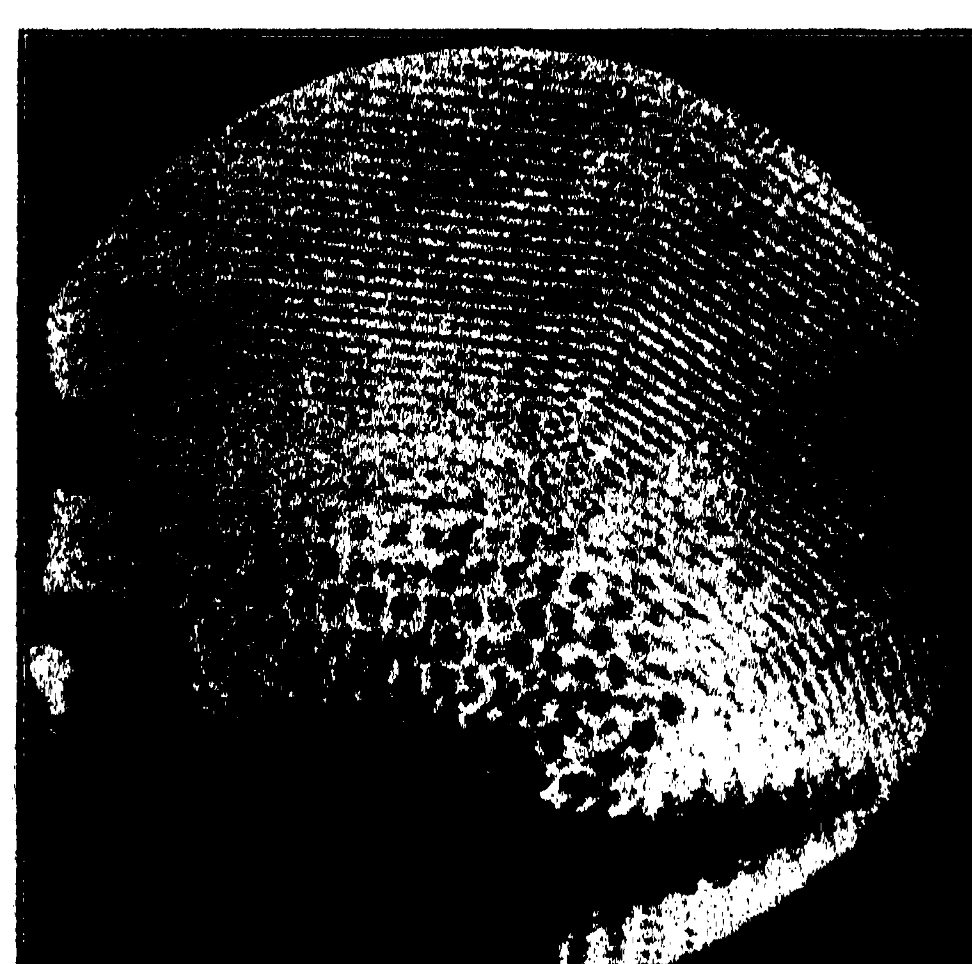


FIG. 4. PHOTOGRAPH OF MERCURY RIPPLES DIFFRACTED BY A GRID.

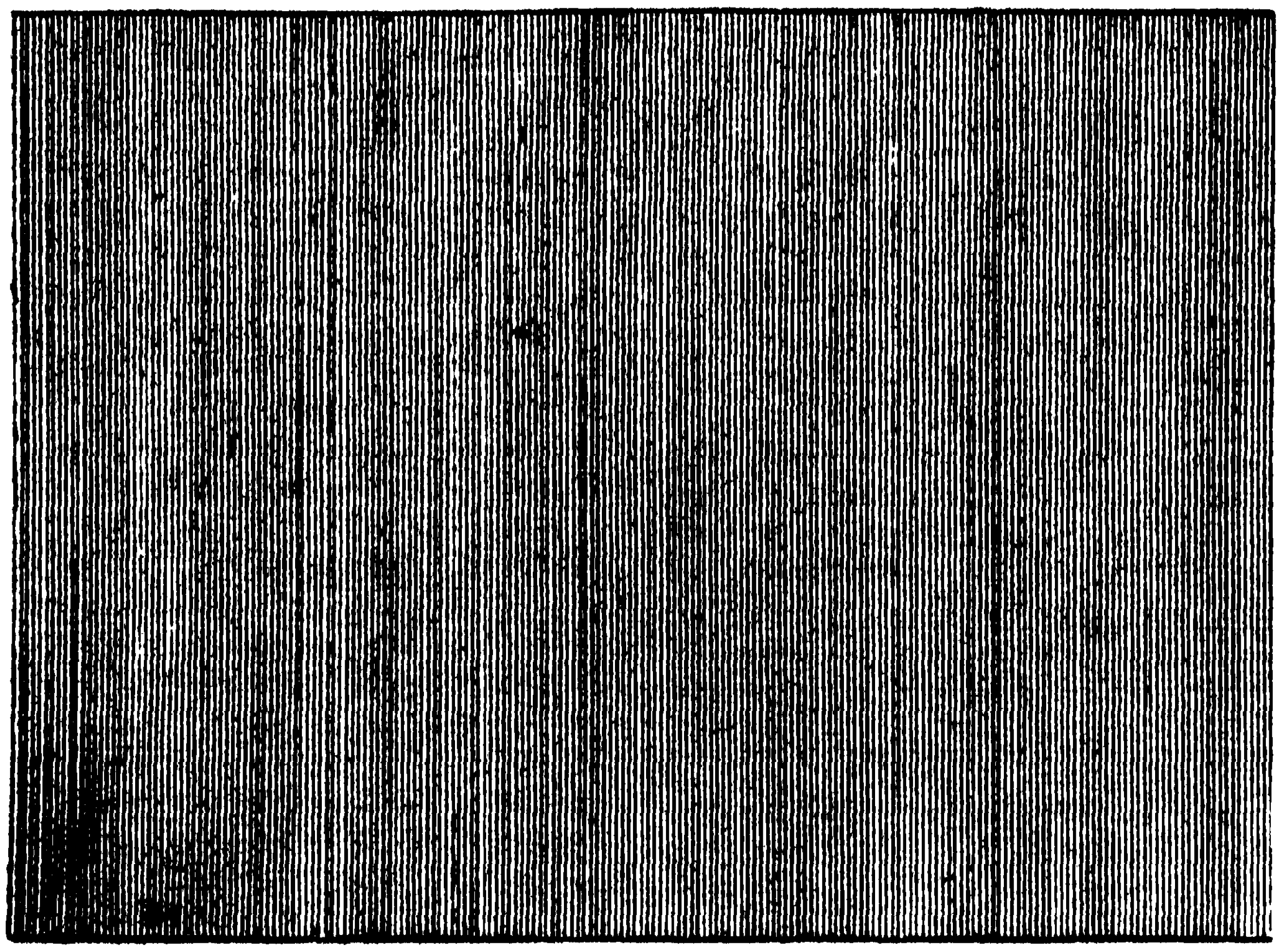


FIG. 5. A PATTERN OF 200 REGULARLY SPACED LINES
WHICH WHEN PHOTOGRAPHED ONTO A LANTERN SLIDE FORMS A DIFFRACTION GRATING FOR EXPERIMENTS ON LIGHT.

We may perform the same experiment with a beam of light. In Fig. 5 is shown a set of some two hundred vertical lines. If these lines are photographed onto a lantern slide, they form a grid through which a beam of light may be made to pass. The upper part of Fig. 6 shows a beam of light as projected from a projection lantern. The middle part of the figure shows the same beam of light, but this time projected through such a lantern slide grid having about one hundred lines to the inch. See how the original spot of light is split into three, a bright one in the center—the direct ray, and a diffracted ray on either side. It is just as in the case of the mercury ripples passing through the grid.

If this is really a case of the diffraction of waves, as we have supposed, if a grating with lines closer together is used, the separation between the diffracted images should be correspondingly greater. The lower part of Fig. 6 shows our beam of light projected this time through a grid photographed with about three hundred lines to the inch. The separation of the diffracted beams is much greater. When these diffracted images are thrown on a screen, one can see that their outer edges are red and their inner edges blue. This means that

FIGS. 6 AND 7. DIFFRACTION OF LIGHT AND X-RAYS
(LEFT.) THE UPPER PORTION IS THE DIRECT BEAM, THE MIDDLE PORTION THAT THROUGH 100 LINES TO THE INCH, AND THE LOWER PORTION PHOTOGRAPHED THROUGH A GRID OF 330 LINES TO THE INCH. (RIGHT.) DIFFRACTION PATTERN OF X-RAYS. D IS THE DIRECT BEAM, O THE DIRECTLY REFLECTED BEAM, AND THE OTHER LINES ARE DUE TO DIFFRACTION.

red light is of the greater wave-length. In fact we could easily from this experiment tell what the wave-length of light is: the distance from the central image to the diffracted image is to the distance from lantern to the screen as the wave-length of the light is to the distance between the lines on the grating. When one carries through the calculation, he finds that the wave-length of light is about one fifty thousandth of an inch.

If we can rely on such a test, light must consist of waves.

Diffraction of X-rays. Precisely similar experiments can, however, be done with X-rays. Fig. 8 shows how we do it. In place of the projection lantern we here have an X-ray tube and a pair of slits. The slide with the lines on it is replaced by a polished mirror on which lines are ruled fifty to the millimeter. Instead of the screen we use a photographic plate. The resulting photograph is shown in Fig. 7. When the ruled mirror is withdrawn we have the single vertical line D. With the grating in place we see a bright central reflected image O with companions on either side. Thus X-rays can also be diffracted, and must therefore, like light, consist of waves.

Light Consists of Particles

For a hundred years no one had seriously questioned the truth of the wave theory. At the close of the last century even the difficulty of supplying a suitable oscillator to give rise to the light waves seemed about to disappear through the discovery of electrons which seemed exactly suited to fill the need. But in 1900 Planck published the results of a long study of the problem of the radiation of heat and light from a hot body. This difficult theoretical study, which has stood the test of time, showed that if a body when heated is to become first red hot, then yellow and then white, the oscillators in it which are giving out the radiation must not radiate continuously as the electromagnetic theory would demand. They must rather radiate suddenly little portions of energy. The amount of energy in each portion must further, according to Planck, be proportional to the frequency. This is the origin of the celebrated "quantum" theory.

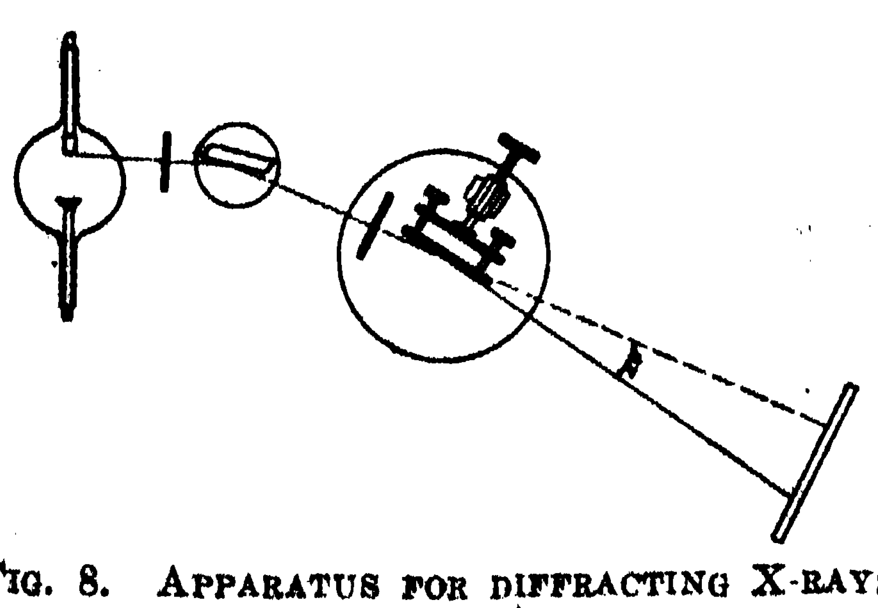


Fig. 8. Apparatus for diffracting X-rays from a ruled reflection grating.

On account of the difficult character of the reasoning involved in Planck's argument, his conclusions carried weight only among those who were especially interested in theoretical physics. Among these was Einstein, who called attention to the fact that Planck's conclusions would fit exactly with the view that the radiation was not emitted in waves at all, but as little particles each possessing a portion of energy proportional to the frequency of the oscillator as Planck had assumed.

Einstein and the photoelectric effect. An opportunity to apply this idea was afforded by the photoelectric effect. It is found that when light as from an arc falls upon certain metals, such as zinc or sodium, a current of negative electricity in the form of electrons escapes from the metallic surface. This photoelectric effect is especially prominent with X-rays, for these rays eject electrons from all sorts of substances. In Fig. 9 you see one of C. T. R. Wilson's photographs of the trails left by electrons ejected by X-rays passing through air and a sheet of copper. These electrons, shot out of the air and the metal

FIG. 9. PHOTOGRAPH OF THE TRACKS OF PHOTO-ELECTRONS EJECTED FROM COPPER BY X-RAYS (WILSON).

by the action of the X-rays, are the X-ray photoelectrons.

The most remarkable property of these photoelectrons is the speed at which they move. We have seen, as in Fig. 10, that X-rays are the waves produced when the cathode electrons bombard a metal target inside the X-ray tube. Let us suppose that a cathode electron strikes the target at a speed of a hundred miles a second (they move tremendously fast). The resulting X-ray, after passing through the walls of the X-ray tube and perhaps a block of wood, may eject a photoelectron from a metal plate placed on the far side. The speed of this photoelectron is then found to be almost as great as that of the original cathode electron.

The surprising nature of this phenomenon may be illustrated by an experience which I had in my early boyhood. During the summer vacations my father would take our family to a lake in northern Michigan. My older brother, who is in the audience this evening, with several of the older boys, built a diving pier around the point a half a mile away from the camp, where the water was deep. Fearing lest something should happen, my mother would not allow us younger boys to swim in this deep water. So we built a diving pier of our own in the shallower water in front of the camp. It so happened, one hot, calm July day, that my brother dove from his diving board into the deep water. The ripples from the resulting splash of course spread out over the lake. By the time they had gone around the point to where I was swimming half a mile away, they were of course much too small to notice. You can imagine my surprise, therefore, when these insignificant ripples, striking me as I was swimming under our diving pier, suddenly lifted me bodily from the water and set me on the diving board!

Does this seem impossible? If it is impossible for a water ripple to do such a thing it is just as impossible for an ether ripple, sent out when an electron dives into the target of an X-ray tube, to jerk an electron out of a second piece of metal with a speed equal to that of the first electron.

It was considerations of this kind which showed to Einstein the futility of trying to account for the photoelectric effect on the basis of waves. He saw, however, that this effect might be ex-

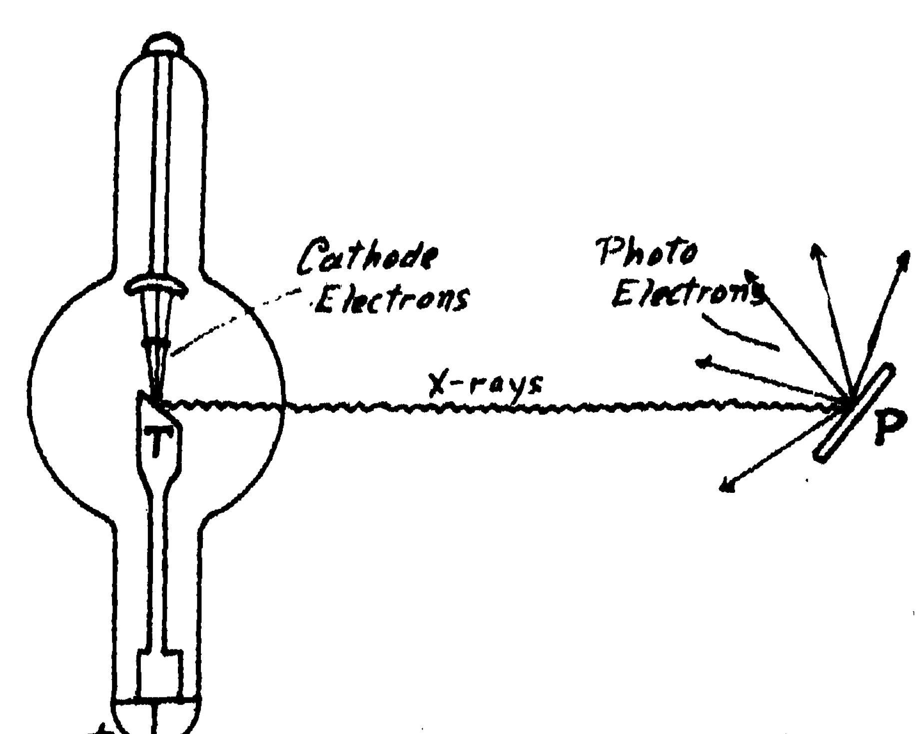


FIG. 10. THE SPEED OF THE PHOTO-ELECTRONS

EJECTED FROM THE METAL PLATE AT P IS ALMOST AS GREAT AS THE SPEED OF THE CATHODE ELECTRONS WHICH PRODUCE THE X-RAYS AT THE TARGET T.

plained if light and X-rays consist of particles. These particles are now commonly called "photons." The picture of the X-ray experiment on this view would be that when the electron strikes the target of an X-ray tube, its energy of motion is transformed into a photon, that is, a particle of X-rays which goes with the speed of light to the second piece of metal. Here the photon gives up its energy to one of the electrons of which the metal is composed, and throws it out with an energy of motion equal to that of the first electron.

In this way Einstein was able to account in a very satisfactory way for the phenomenon of the ejection of electrons by light and X-rays.

Peculiar X-ray echoes. Even more direct evidence that light consists of particles has come from a study of X-ray echoes. If you hold a piece of paper in the light of a lamp, the paper scatters light from the lamp into your eyes. In the same way, if the lamp were an X-ray tube, the paper would scatter X-rays into your eyes. If light and X-rays are waves, scattered X-rays are like an echo. When one whistles in front of a wall, the echo comes back with the same pitch as the original sound. This must be so, for each wave of the sound is reflected from the wall, as many waves return as strike, and the frequency or pitch of the echoed wave is the same as that of the original wave. In the case of scattered X-rays, the echo should similarly be thrown back by the electrons in the scattering material, and should likewise have the same pitch or frequency as the incident rays.

We measured the pitch of the X-ray echoes a few years ago at St. Louis, using the apparatus shown in Fig. 11. Rays from the target *T* of the X-ray tube were scattered by a block of carbon at *R*, and the pitch, or wave-length, of the echoed rays was measured by an X-ray spectrometer. By swinging the tube itself in

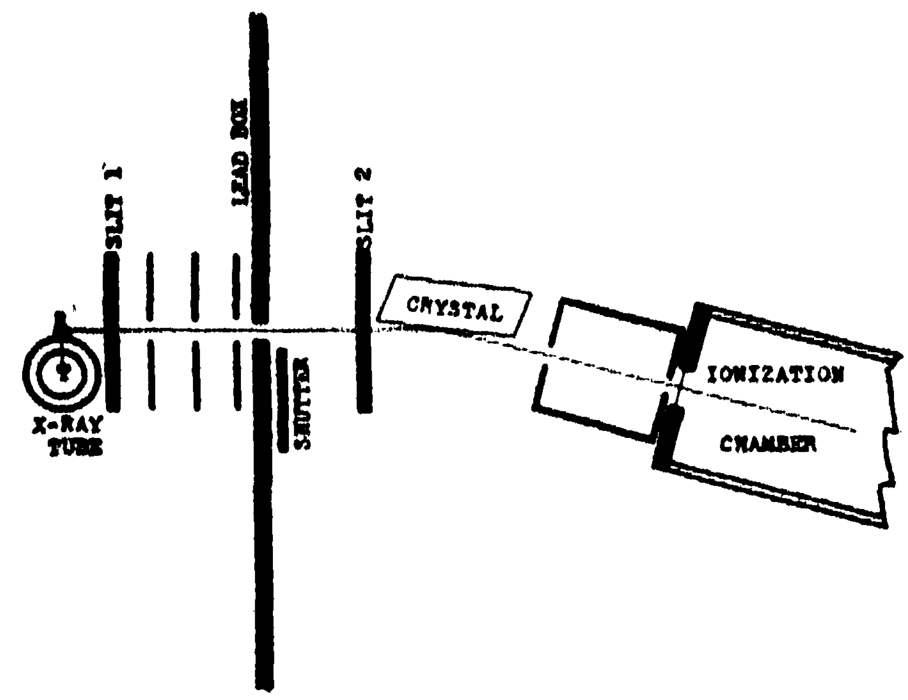


FIG. 11. THE WAVE-LENGTH OF THE X-RAYS

SCATTERED FROM A PIECE OF CARBON AT *R* IS MEASURED BY REFLECTION FROM A CRYSTAL.

line with the slits, it was possible to get a direct comparison with the wave-length of the original rays.

Fig. 12 shows the result of the experiment. Above is plotted the spectrum of the original X-ray beam. Below is shown the spectrum of the X-rays scattered in three different directions. A part of the scattered rays are of the original wave-length; but as you see, most of them are increased in wave-length. This would correspond to a lower pitch for the echo than for the original sound.

As we have seen, this change in wave-length is contrary to the predictions of the wave theory. If we take Einstein's idea of X-ray particles, however, we find a simple explanation of the effect. On this view, we may suppose that each photon of the scattered X-rays is deflected by a single electron, Fig. 13. Picture to yourselves a golf ball bouncing from a football. A part of the golf ball's energy is spent in setting the football in motion. Thus, the golf ball bounces off having less energy than when it struck. In the same way, the electron from which the X-ray photon bounces will recoil, taking part of the photon's energy, and the deflected photon will have less energy than before it struck the electron. This reduction in energy

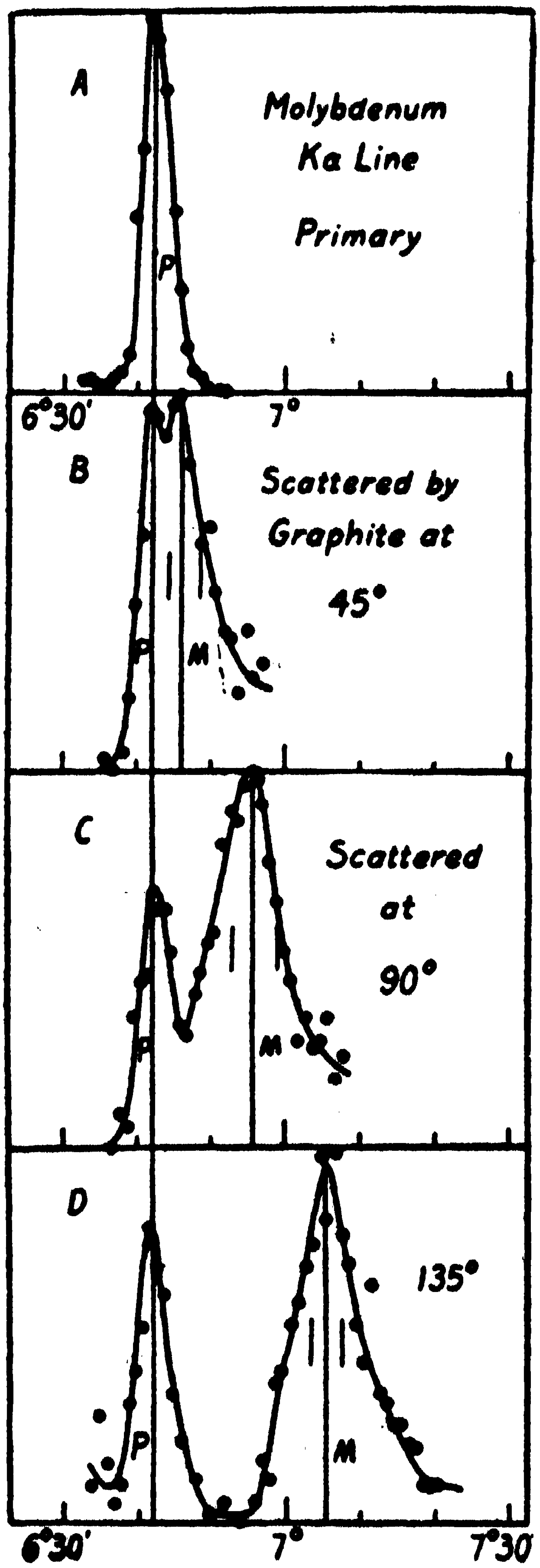


FIG. 12. SPECTRA OF SCATTERED X-RAYS (BELOW) COMPARED WITH THE SPECTRUM OF THE ORIGINAL X-RAY (ABOVE).

of the X-ray photon corresponds, according to Planck's original quantum theory, to a decrease in frequency of the scattered X-rays, just as the experiments show. In fact, the theory is so definite that it is possible to calculate just how great a change in frequency should

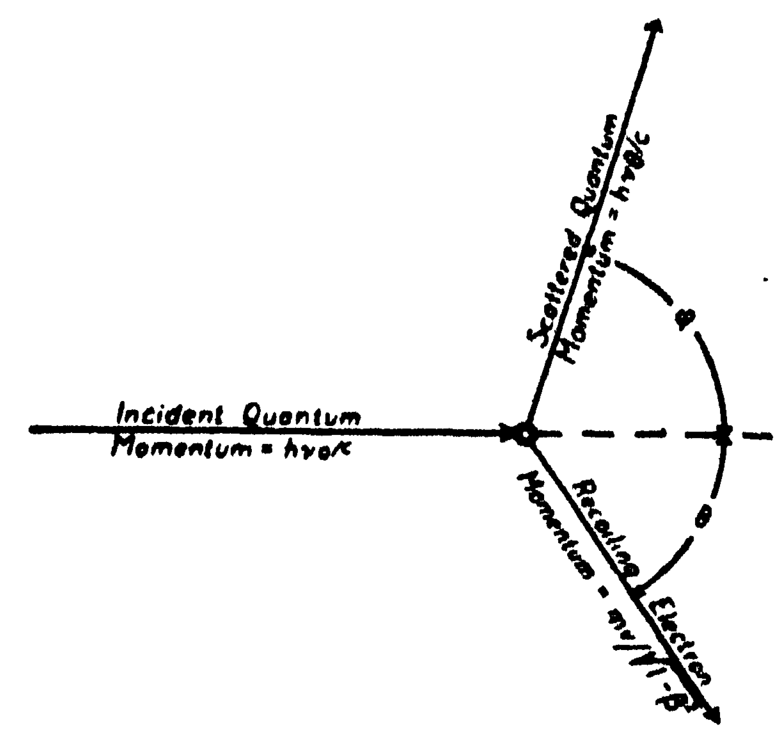


FIG. 13. RECOIL OF AN ELECTRON
WHEN AN INCIDENT X-RAY PHOTON GLANCES FROM AN ELECTRON, THE ELECTRON RECOILS FROM THE IMPACT, TAKING PART OF THE PHOTON'S ENERGY.

occur, and the calculation is found to correspond accurately with the experiments.

Playing billiards with photons and electrons. If this explanation is the correct one, it should however be possible to find the electrons which recoil from the impact of the X-ray particles. Before this theory of the origin of scattered X-rays was suggested, no such recoiling electrons had ever been noticed. Within a few months after its proposal, however, C. T. R. Wilson succeeded in photographing the trails left when electrons in air recoil from the X-rays which they scatter. Fig. 14 shows one of his typical photographs. The X-rays here are going from left to right. At top and bottom you notice the long trails left by two photoelectrons, which you recall have taken up the whole energy of a photon. In between are a number of shorter trails, all with their tails toward the X-ray tube. These are the electrons which have been struck by flying X-ray photons. Some have been struck squarely, and are knocked straight ahead. Others have received only a glancing blow, and have recoiled at an angle. Thus we have observed not only the loss in energy of the deflected photons, as shown by the lowering in

FIG. 14. RECOIL ELECTRONS
THE SHORTER TRACKS PROCEED ALMOST IN THE DIRECTION OF THE INCIDENT X-RAYS.

pitch of the X-ray echo, but we have found also the recoiling electrons from which the photons have bounced.

In order, however, to satisfy ourselves by a crucial test whether X-rays act like particles, an experiment was devised which would enable us to follow at the same time the photon as it is deflected by an electron, and the motion of the recoiling electron. In Fig. 15 we see at the left what we may call the X-ray gun, which shoots a few X-rays through a cloud expansion chamber. In this chamber is photographed the trail of every electron set in motion by the X-rays. So feeble a beam of X-rays is used that on the average only one or two recoil electrons will appear at a time. Let us suppose, as in the figure, that the electron struck by the X-ray particle recoils downward. This must mean that the X-ray particle has been deflected upward toward A. If this X-ray should strike another electron before it leaves the chamber, this event must occur at some point along the line OA. It can not occur on the same side as the recoil electron. If, however, the X-ray is a wave, spreading in all directions, there is no more reason why the second electron associated with the scattered ray should appear at A than at B. A series of photographs which shows the relation between the direction of recoil of the scattering electron *R* and the location of the second electron struck by the scattered X-ray, thus affords a crucial test between the conceptions of X-rays as spreading waves and X-rays as particles.

From a large number of photographs taken in this manner it has become evi-

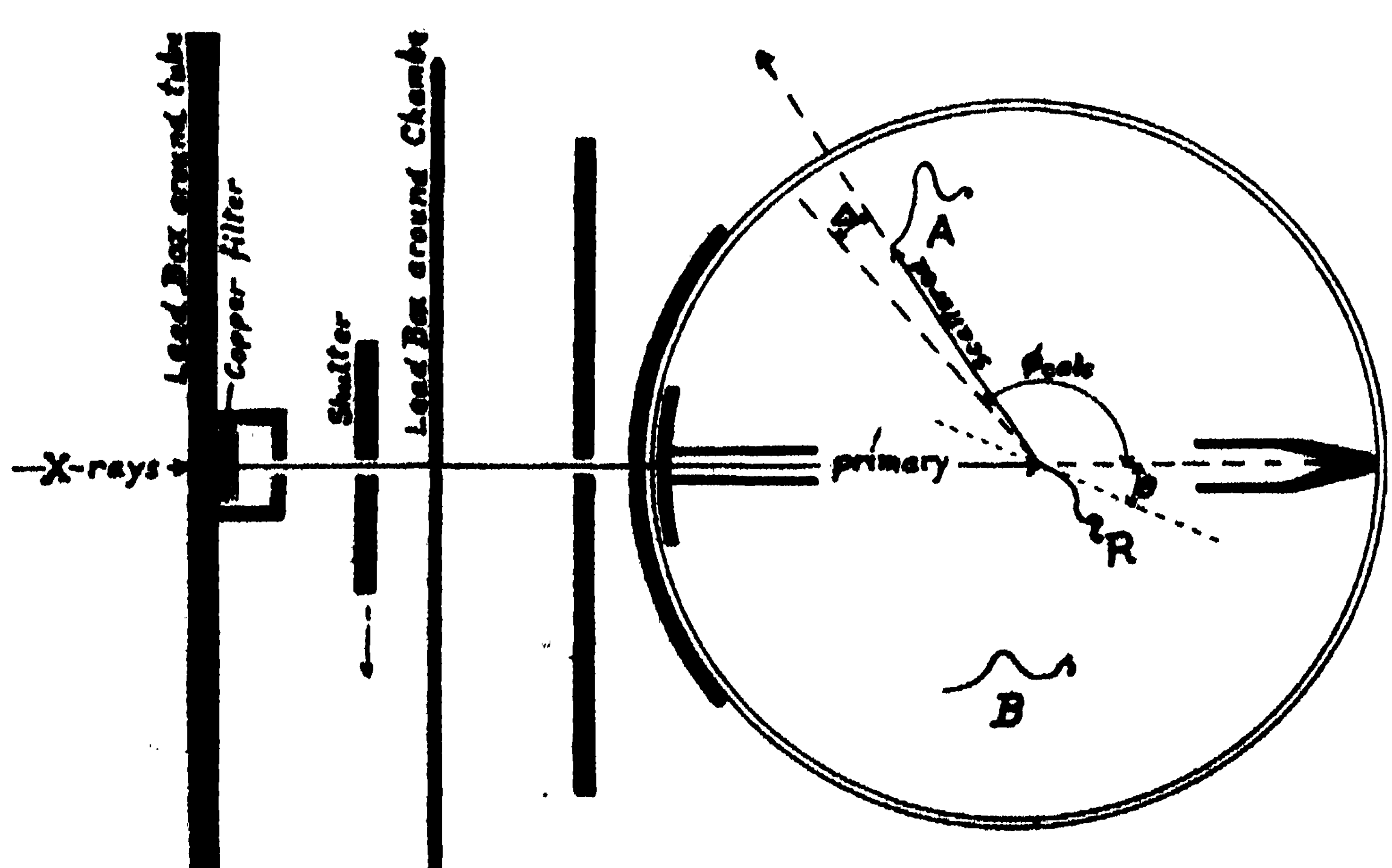


FIG. 15. DIAGRAM OF AN EXPERIMENT
IN WHICH ONE OBSERVES BOTH THE RECOILING ELECTRON AND THE DIRECTION IN WHICH THE DEFLECTED PHOTON PROCEEDS.

dent that an X-ray is scattered in a definite direction, like a particle. But if X-rays, so also all the rest of the family of electromagnetic radiations. It would thus seem that by these experiments Einstein's notion of light as made up of particles is established.

The Paradox of Waves and Particles

We thus seem to have satisfactory proof from our interference and diffraction experiments that light consists of waves. The photoelectric and scattering experiments afford equally satisfactory evidence that light consists of particles. How can these two apparently conflicting concepts be reconciled?

Electron waves. Before attempting to answer this question, let me call to your attenton the fact that this dilemma applies not only to radiation but also in other fundamental fields of physics. When the evidence was growing strong that radiation, which we had always thought of as waves, had also the properties of particles, L. de Broglie, of Paris, asked himself, may it not then be possible that electrons, which we know as particles, may have the properties of waves? An extension of Planck and Einstein's quantum theory enabled him to calculate what the wave-length corresponding to a moving electron should be. In photographs like Figure 9 we have ocular evidence that electrons are very real particles indeed. Nevertheless, de Broglie's absurd suggestion was promptly subjected to experimental test by Davisson and Germer at New York, and later by Thomson at Aberdeen and others.

Let me describe Thomson's experiments, which are typical of them all. You will recall that our crucial evidence for the wave character of light was the fact that light could be diffracted by a grating of lines ruled on glass. X-rays were diffracted in the same way; but before this had been shown possible, it was found that X-rays could be dif-

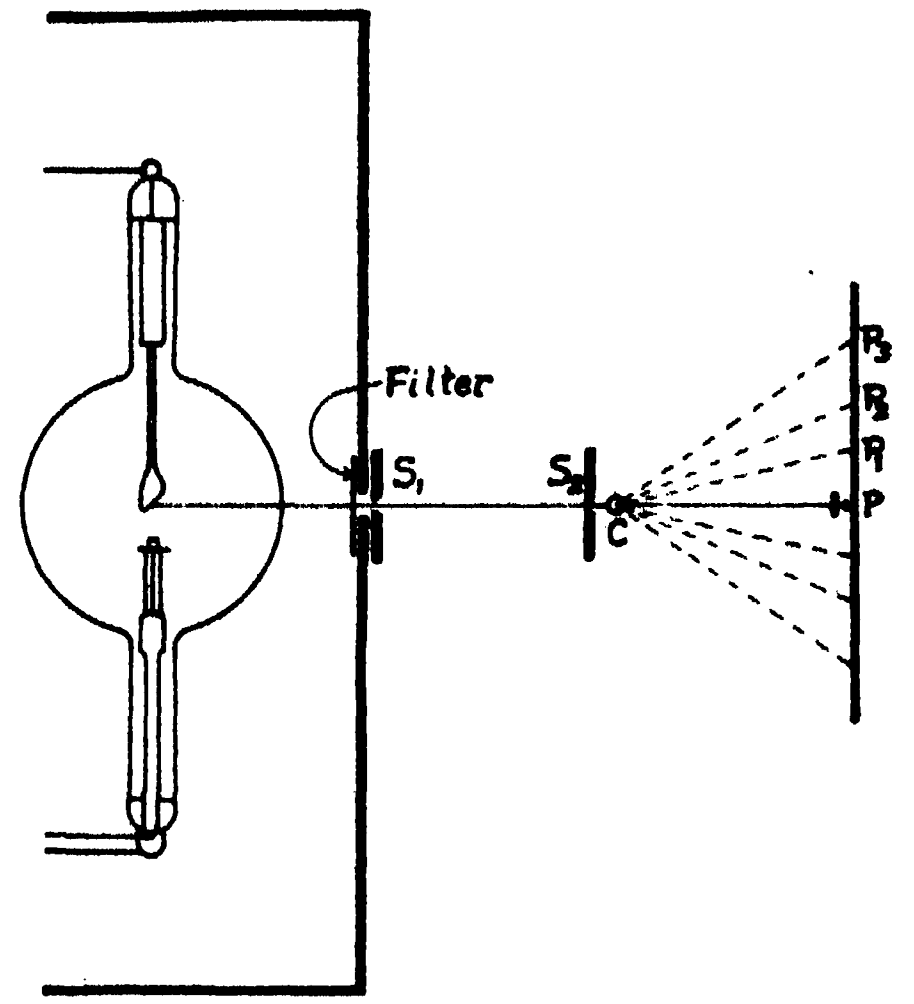


FIG. 16. HULL'S ARRANGEMENT
FOR DIFFRACTING A BEAM OF X-RAYS BY A MASS OF POWDERED CRYSTALS.

fracted by the regularly arranged atoms in a crystal. The layers of atoms took the place of the lines ruled on glass. Fig. 16 shows how this experiment has been done by Dr. Hull, at Schenectady. X-rays pass through a pair of diaphragms and a mass of powdered crystals placed at C, and strike a photographic plate at P. Rays diffracted by the layers of atoms in the crystal strike at such points as P_1, P_2, etc., giving rise to a series of rings about the center. If a mass of powdered aluminum crystals is placed at C, Hull obtains the photograph shown in Fig. 17 (upper). You see the central image, and around it the diffraction rings. It was this crystal diffraction that first gave convincing evidence that X-rays, like light, consist of waves.

G. P. Thomson has performed a precisely similar experiment with electrons. The X-ray beam in the last slide was replaced by a beam of cathode electrons, and gold leaf took the place of the aluminum. The resulting photograph is shown in Fig. 17 (lower). Though it is not quite as sharp as the photograph taken with the X-rays, we can see distinctly the central image, and several

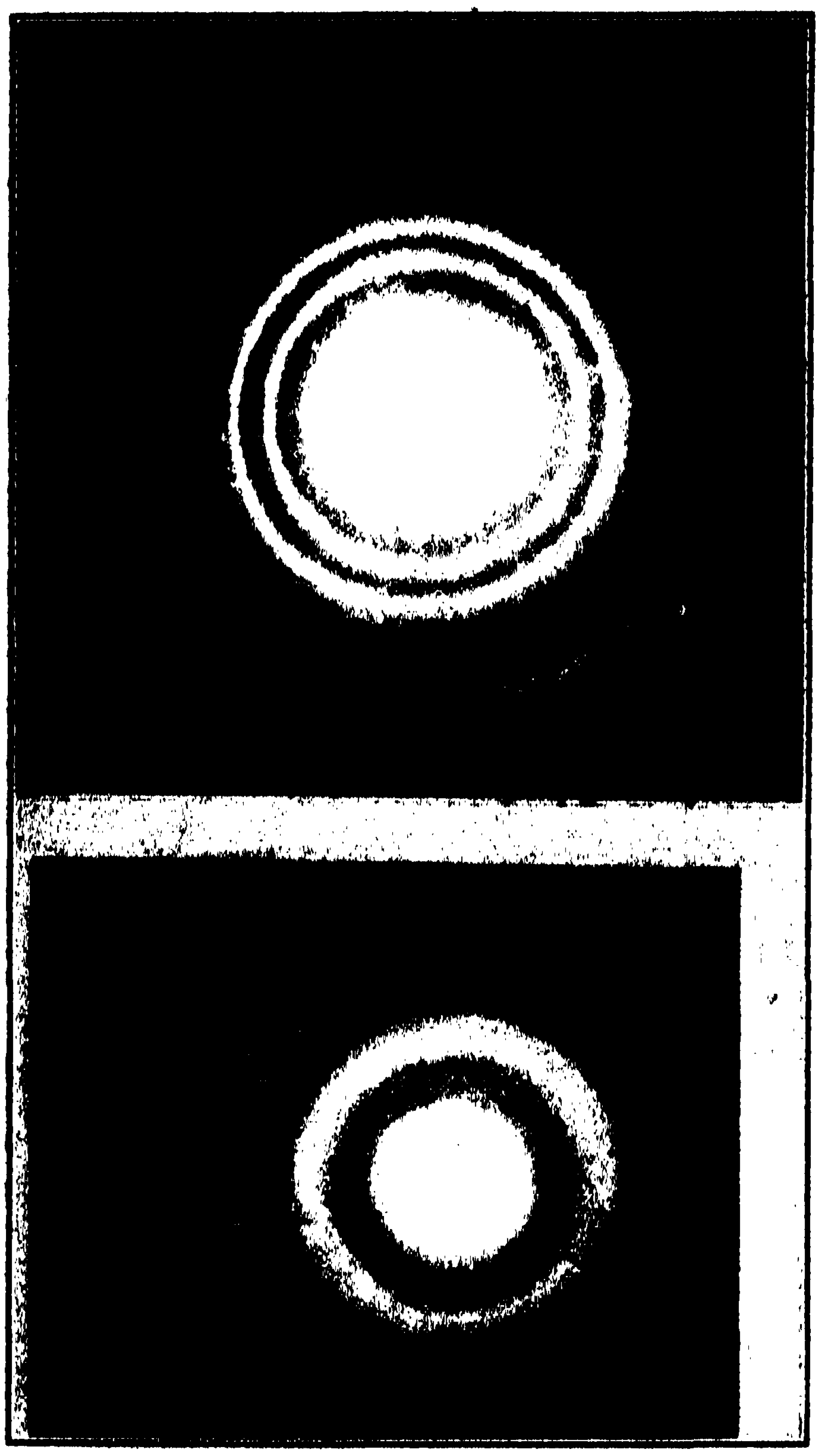


FIG. 17. THE DIFFRACTION PATTERN (UPPER) PRODUCED WHEN A BEAM OF X-RAYS TRAVERSES A MASS OF ALUMINUM CRYSTALS (HULL). (LOWER) PRODUCED WHEN A BEAM OF ELECTRONS TRAVERSES A MASS OF GOLD CRYSTALS (G. P. THOMSON).

rings of diffracted electrons. If the last slide demonstrated the wave character of X-rays, does not this slide prove equally definitely the wave character of electrons?

Most of you are aware of the fact that J. J. Thomson, the famous old Cavendish professor of physics at Cambridge, was largely responsible for proving that cathode rays are electrified particles. About a year ago my wife and I were paying Sir Joseph and Lady Thomson a Sunday afternoon call, and found their son, G. P. Thomson, home from Aberdeen for a week-end. He had with him this photograph, Fig. 17 (lower) showing the diffraction of cathode rays by crystals of gold. It was a really dramatic occasion to see the great old man of science, who had spent his best years showing that electrons are particles, full of enthusiasm over his son's achievement of finding such convincing evidence that moving electrons are waves.

We are thus faced with the fact that the fundamental things in nature, matter and radiation, present to us a dual aspect. In certain ways they act like particles, in others like waves. The experiments tell us that we must seize both horns of the dilemma.

A SUGGESTED SOLUTION

During the last year or two there has gradually developed a solution of this puzzle, which though at first rather difficult to grasp, seems to be free from logical contradictions and essentially capable of describing the phenomena which our experiments reveal. A mere mention of some of the names connected with this development will suggest something of the complexities through which the theory has gradually gone. There are Duane, Slater and Swann in this country, de Broglie in France, Heisenberg and Schrödinger in Germany, Bohr in Denmark, Dirac in England, among others, who have contributed to the growth of this explanation.

The point of departure of this theory is the mathematical proof that the dynamics of a particle may be expressed in terms of the propagation of a group of waves. That is, the particle may be replaced by a wave train—the two, so far as their motion is concerned, may be made mathematically equivalent. The motion of a particle such as an electron or a photon in a straight line is represented by a plane wave. The wavelength is determined by the momentum of the particle, and the length of the train by the precision with which the momentum is known. In the case of

the photon, this wave may be taken as the ordinary electromagnetic wave. The wave corresponding to the moving electron has received no generally accepted name, other than the Greek letters Ψ $\bar{\Psi}$. Perhaps we may call it, however, by the name of its inventor, a de Broglie wave.

Consider, for example, the deflection of a photon by an electron on this basis, that is, the scattering of an X-ray. The incident photon is represented by a train of plane electromagnetic waves. The recoiling electron is likewise represented by a train of plane de Broglie waves propagated in the direction of recoil. These electron waves form a kind of grating by which the incident electromagnetic waves are diffracted. The diffracted waves represent in turn the deflected photon. They are increased in wave-length by the diffraction because the grating is receding, resulting in a Doppler effect.

In this solution of the problem we note that before we could determine the direction in which the X-ray was to be deflected, it was necessary to know the direction of recoil of the electron. In this respect the solution is indeterminate; but its indeterminateness corresponds to an indeterminateness in the experiment itself. There is no way of performing the experiment so as to make the electron recoil in a definite direction as a result of an encounter with a photon. It is a beauty of the theory that it is determinate only where the experiment itself is determinate, and leaves arbitrary those parameters which the experiment is incapable of defining.

It is not usually possible to describe the motion of either a beam of light or a beam of electrons without introducing both the concepts of particles and waves. There are certain localized regions in which at a certain moment energy exists, and this may be taken as a definition of what we mean by a particle. But in predicting where these localized positions are to be at a later instant, a consideration of the propagation of the corresponding waves is usually our most satisfactory mode of attack.

Attention should be called to the fact that the electromagnetic waves and the de Broglie waves are according to this theory waves of probability. Consider as an example the diffraction pattern of a beam of light or of electrons, reflected from a ruled grating, and falling on a photographic plate. In the intense portion of the diffraction pattern there is a high probability that a grain of the photographic plate will be affected. In corpuscular language, there is a high probability that a photon or electron, as the case may be, will strike this portion of the plate. Where the diffraction pattern is of zero intensity, the probability of a particle striking is zero, and the plate is unaffected. Thus there is a high probability that a photon will be present where the "intensity" of an electromagnetic wave is great, and a lesser probability where this "intensity" is smaller.

It is a corollary that the energy of the radiation lies in the photons, and not in the waves. For we mean by energy the ability to do work, and we find that when radiation does anything it acts in particles.

In this connection it may be noted that this wave-mechanics theory does not enable us to locate a photon or an electron definitely except at the instant at which it does something. When it activates a grain on a photographic plate, or ionizes an atom which may be observed in a cloud expansion chamber, we can say that the particle was at that point at the instant of the event. But in between such events the particle can not be definitely located. Some positions are more probable than others, in proportion as the corresponding wave is more intense in these positions. But there is no definite position that can be assigned to the particle in

between its actions on other particles. Thus it becomes meaningless to attempt to assign any definite path to a particle. It is like assigning a definite path to a ray of light: the more sharply we try to define it by narrow slits, the more widely the ray is spread by diffraction.

It is only to satisfy our sense of continuity that we assume that an electron or a photon has a real existence between the occasions at which it acts on other particles. It would be equally permissible to suppose that light or cathode rays alternate in form between particles and waves. While moving from one place to another they would spread out as waves, but when producing any physical effect they would materialize into discrete particles.

Perhaps enough has been said to show that by grasping both horns we have found it possible to overcome the dilemma. Though no simple picture has been invented affording a mechanical model of a light ray, by combining the notions of waves and particles a logically consistent theory has been devised which seems essentially capable of accounting for the properties of light as we know them.

Radio rays, heat rays, visible and ultra-violet light, X-rays, gamma rays and cosmic rays, all are thus different varieties of light. We find from our experiments on diffraction and interference that light consists of waves. The photoelectric effect and the scattering of X-rays give equally convincing reasons for believing that light consists of particles. For centuries it has been supposed that the two conceptions are contradictory. Goaded on, however, by obstinate experiments, we seem to have found a way out. We continue to think of light propagated as electromagnetic waves; but whenever the light does something, it does it as photons. In reply to our question, what is light, the answer seems to come, waves and particles, light is both.

THE SIBUTU ISLANDS

By Professor ALBERT W. HERRE
ZOOLOGY MUSEUM, STANFORD UNIVERSITY

TWENTY-ONE miles southwest from the rest of the Sulu Archipelago, and therefore forming the southernmost extension of the Philippines, lies the small Sibutu group. Geographically and ethnologically, it belongs to Borneo.

The Sibutu group includes the following inhabited islands: Sibutu, Tumindao, Sitankai, Omapui, Sipankot and Bulubulu. It also comprises a number of small uninhabited islands and many reefs and shoals exposed at low tide. At the north is the deep mediterranean known as the Sulu Sea, and on the south is the still deeper Celebes Sea. Connecting these two is the broad Sibutu Passage, separating these islands from the rest of the Philippines.

This passage has a depth of from about 100 to 685 fathoms, and is remarkable for the powerful current, locally feared and notorious. In the Samal language this current is known as the "House." During the season of the southwest monsoon the House flows continuously from the Sulu Sea into the Sea of Celebes, with a velocity of five to ten nautical miles an hour. For two or three months, when the current is at its maximum, it is unsafe or even impossible for small launches or the native sailing craft to cross the House. When caught in this current, small boats are often carried southward and landed on the coast of North Celebes or in Dutch Borneo.

Running through the Sibutu group are several deep channels of varying widths, the widest perhaps two miles in breadth, none of them over 150 fathoms in depth. A current similar to the House flows through each of them, but in none of them does it attain a notable or dangerous velocity.

During the period of the northeast monsoon the currents are reversed in all these passages, and flow continuously from the Sea of Celebes into the Sulu Sea. The north-bound currents never attain high velocity, averaging three or four knots an hour, and they have no distinctive name. It gives one a queer sensation to observe these currents moving onward continuously, never slacking, never hurrying, unchanged by the ebb and flow of the tides, day and night and week after week, as though some great river were moving on steadily and majestically. Due to the influence of these currents the fish fauna of the Sulu Archipelago is essentially identical with that of Celebes and the Moluccas.

The Sibutu group is composed of low flat islands, which with but one exception do not rise much above high tide. Such islands, due to their uniformity of structure and topography, offer little variety of animal and plant life, but to the marine biologist they are of intense interest, while the people dwelling upon or about them are very little known and would repay careful study. The Sibutu group has long been known as a fishing ground of the first importance in the Philippines and offers an excellent opportunity for the development of commercial fisheries along modern lines.

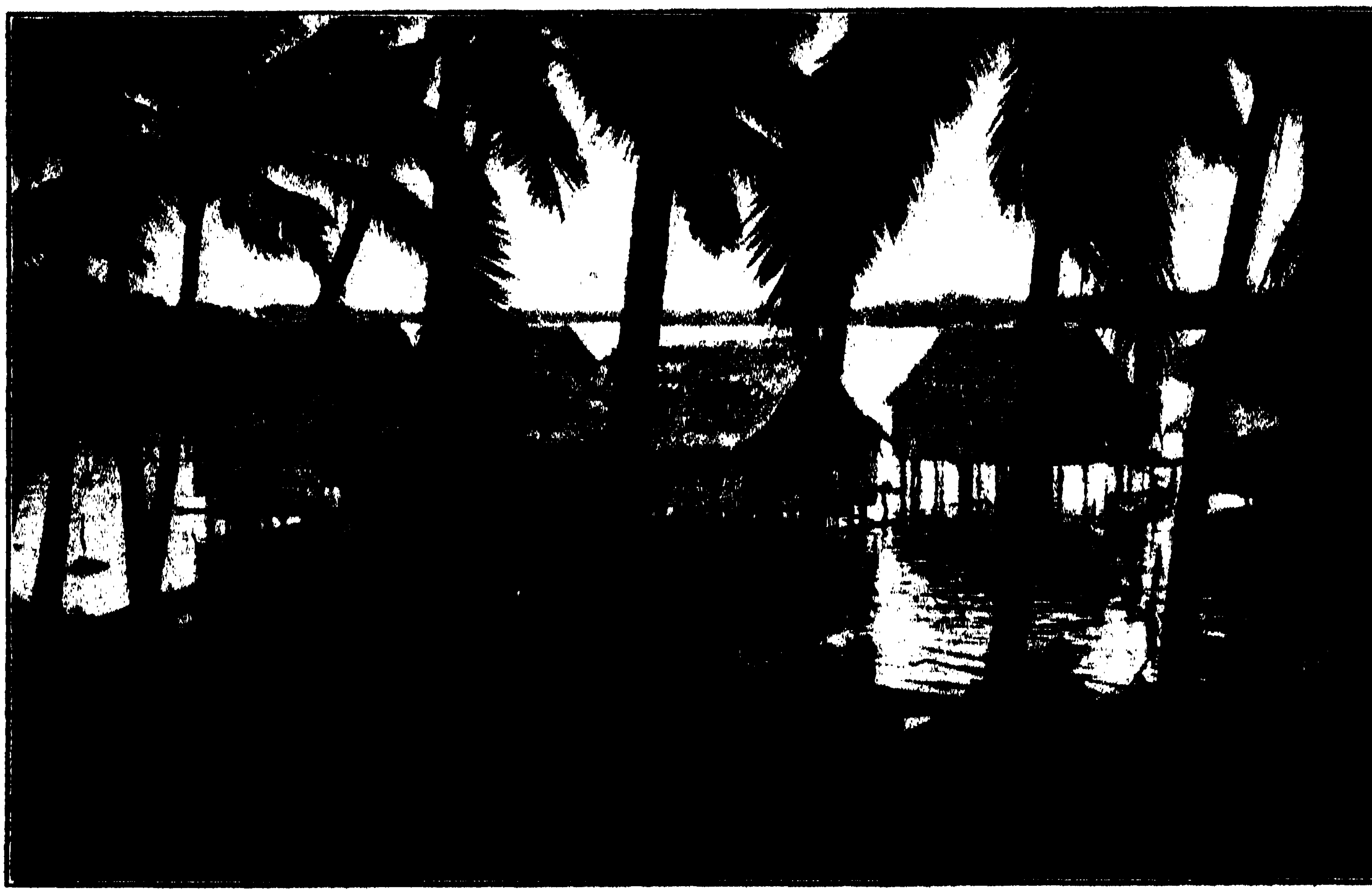
The largest island is Sibutu, with a length of eighteen and one half miles, and an average breadth of about two and a fourth miles. On the eastern coast of Sibutu, eight or more miles south of its northern tip, is a hill five hundred feet high. It is locally known as the "Mountain," and forms a landmark visible for a great distance at sea, and is an important recognition mark for navigators. This hill is apparently of volcanic origin

DATU MAMA—A TAU SUG NOBLEMAN WITH TEN OF HIS FOURTEEN WIVES

and great blocks of granite are plentifully strewn over its slopes.

All the rest of the island is merely a vast coral reef in many places, if not indeed most, but little changed since it lay beneath the sea ages ago. Around the northern end of the island and along its western shore for many miles, except where the village of Sibutu is located, the shore line is elevated abruptly from

TAO SUG FIGHTING MEN—JOLO



A SAMAL VILLAGE—SULU ARCHIPELAGO

four to eight feet above high-tide level. The base of this elevated portion is, of course, usually more or less undercut by wave action, so that in many places this slight elevation is very difficult to surmount by one approaching from the sea. Elsewhere the shore line is a more or less gently sloping sandy beach of moderate width.

A mile or so north of the village of Sibutu the land back of the beach is raised fifteen or twenty feet above the general level of the island. This elevated portion extends back toward the interior for a half mile or so and runs northward several miles. It was evidently the first portion of the reef to be raised out of the sea and is therefore the oldest part of the island.

Surrounding the island is a reef of dead and living coral which is more or less bare at low tide but is everywhere completely submerged at high tide. This reef varies from a few dozen yards to nearly a mile in breadth and rises everywhere from deep water except at the southern tip of Sibutu. Here the reef forms a southward extension of slight depth until it emerges again as Saluag island, the southernmost extremity of the Philippines.

On the southeast coast of Sibutu the reef forms a lagoon; at its south end this lagoon is very narrow and only deep enough for bancas, lipas and other flat-bottomed native craft. It gradually widens northward, till at the village of Tandu Banak it attains its maximum breadth. Opposite Tandu Banak there is an opening in the outer shore line of the lagoon where launches and other keel-built boats drawing five or six feet of water can find entrance and proceed southward in the lagoon for several miles. On the other side of the island, beginning near the southern end of the village of Sibutu, the reef widens out and forms a sort of very shallow lagoon, mostly bare at low tide, which has a maximum breadth of half a mile. It is very evident that the island of Sibutu has been formed by three successive elevations of the coral reef, the portion last raised being partly above and partly below the level of low tide.

Sibutu is everywhere covered with a more or less dense growth of shrubbery and forest trees, except at the site of present or past villages. Owing to the comparatively xerophytic conditions, there are few creepers or lianas of any size, so that it is not difficult to penetrate the jungle in most places. Few of the trees are of even medium size, though there are some moderately large worthless trees of the genus *Ficus*. Nearly all the trees of any size were cut during the past twenty years to make railroad ties for use in Luzon and the Visayas.

Any one landing at a village on the island and going no farther in than the houses along the shore might well believe Sibutu to have deep fertile soil, ready for the plow when cleared. A trip across the island, or even a few hundred yards back into the jungle, tells a very different story. One walks continuously on coral, most of it apparently unchanged since it was first elevated from the depths of the sea. The surface is very rough and uneven and has more or less soil present in its holes and depressions, but nowhere can one find a continuous layer of soil after leaving the shore line three hundred yards or so behind.

Scattered over the rock everywhere, or embedded in its upper portion, are fossil mollusks in great variety. They are all of the same species that one finds a short distance away in the sea. Most conspicuous of them are the ponderous shells of the great *Tridacnas* or giant clams.

About a mile behind the village of Sibutu, and running northward for several miles, is a broad strip of territory which is of an extraordinary character.

A GROUP OF SAMAL FISHERMEN, TAWI TAWI, SULU ARCHIPELAGO

THESE MEN WILL SAIL 150 TO 175 MILES ACROSS THE OPEN SULU SEA WITHOUT CHART OR COMPASS AND BRING UP AT THEIR DESTINATION WITH ABSOLUTE CERTAINTY.

SAMAL FISHERMEN

GETTING READY TO SAIL ACROSS THE SULU SEA TO PALAWAN OVER 150 MILES OF OPEN WATER.

It is truly remarkable for the incredible number of large, more or less circular, holes contained in this part of the old coral reef. Holes, just plain holes! There they are by the tens of thousands, of all sizes and depths, so closely set together that the ancient reef is riddled like a sieve.

Holes! One sees nothing else! Unbelievable numbers of holes, the ancient fossil reef so thickly spattered with them that for miles hardly a square yard of entire surface can be found. Some are just the right size and depth to take in a man's foot and leg up to the knee, and woe be to the person who should slip into one while walking rapidly, for it would be only too easy to injure his knee joint irreparably. Other holes are of all possible sizes up to enormous pits twenty feet deep and at least five feet in diameter, their sides great vertical stone walls impossible to scale. A man in the bottom of one of those cylindrical well-like holes would be absolutely helpless. In the daytime one must pick and choose his path with great care, while travel at night is entirely out of the question as it is impossible to go ten feet in any direction without landing in a hole. In many places the trail is not over a foot wide, with a yawning hole on either side, while the path winds like a writhing serpent. A slide into any one of those innumerable pits would mean a miserable death, especially if one were wedged head first in a hole just large

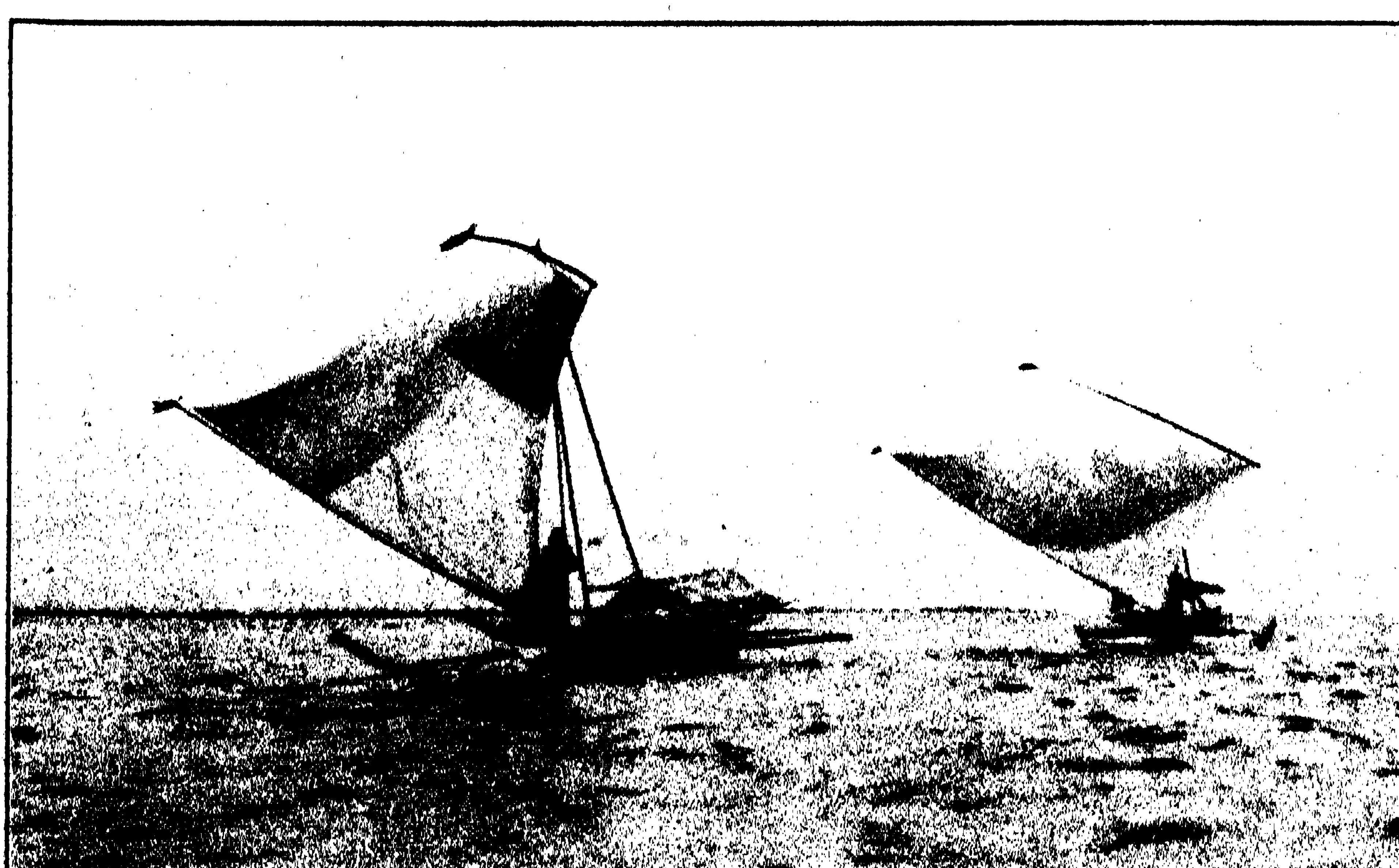
enough to fit a man snugly. Yet this could very easily happen if a person stumbled. This whole region is one of weird spookiness, and constant vigilance is necessary to prevent a distressing accident.

About half a mile northwest of the Mountain, not southwest as indicated on the maps, is a permanent pool of water known locally as the "Lake." It occupies a chasm in the ancient reef and is perhaps forty to fifty feet wide. The surface of the water is about twenty-five feet below the level of the surrounding land, and at one place it is possible to descend almost to the level of the water, which is about thirty-five feet deep. On two sides of the chasm the walls of the pool are cavernous, and the water extends back into the cave thus formed nearly as far as the breadth of the open pool. It reminds one of the water holes of Yucatan, though of course it is very shallow compared to them. At one end a huge *Ficus* adds to the picturesqueness of the pool by its vast and intricately branching intertangled mass of roots clambering over the sides and trailing in the water.

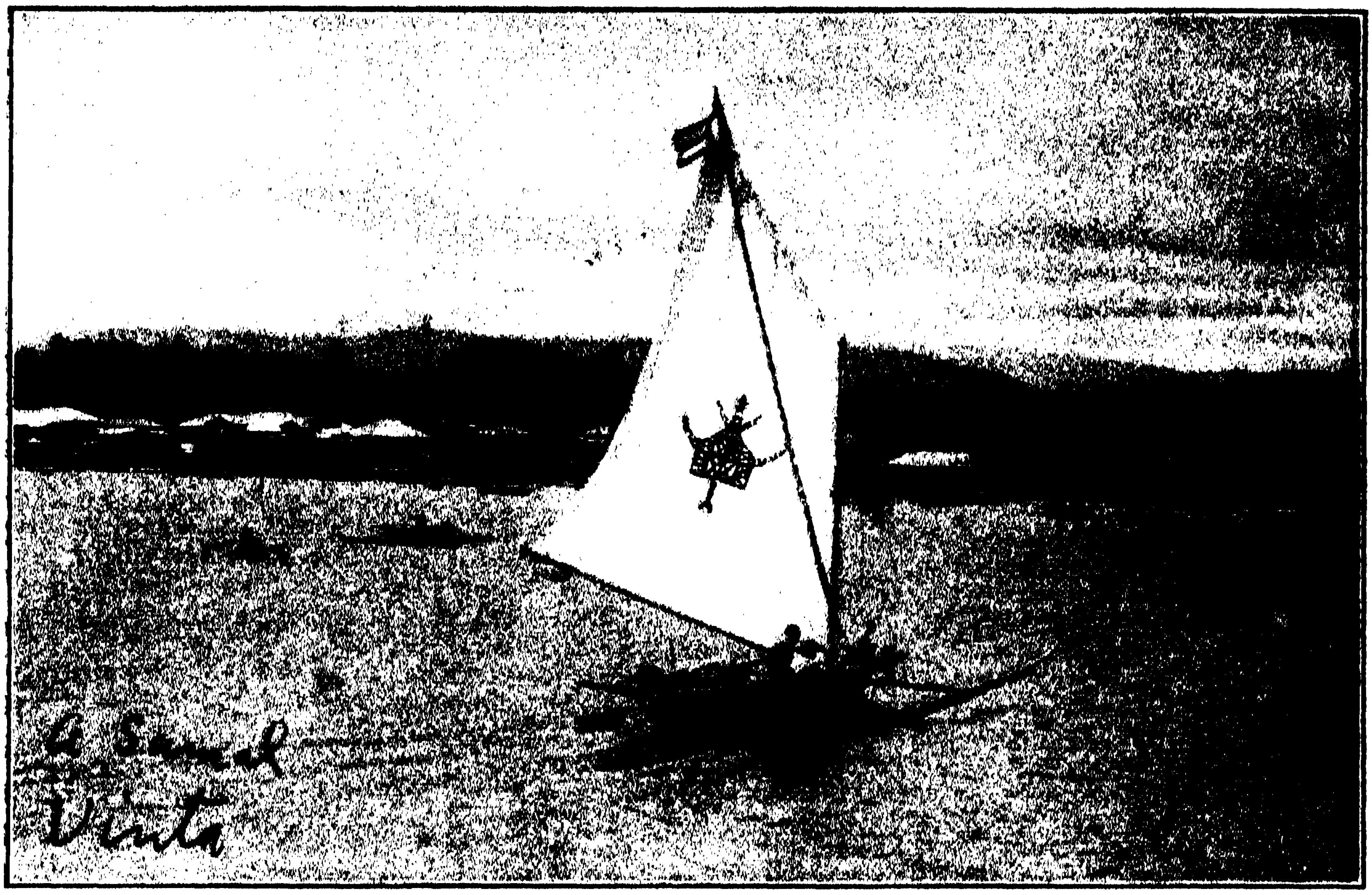
At the southern base of the Mountain is a swale and in and around it is the only body of real soil on the island; here several acres of deep black loam occur.

Wild hogs are abundant on the island and, as elsewhere throughout the Philippines, are a constant menace to agriculture. Monkeys are plentiful, and at low tide family groups throng over the exposed reef, picking up crabs, limpets, clams and other sea delicacies. There are no other native mammals larger than rats, except the great fruit bats, which may have a spread of wing of three to five feet, and are very destructive to young coconuts. That most interesting bird, the tabang or brush turkey, a large Megapode, is abundant everywhere. These curious birds lay their eggs in a great mound of decaying vegetation and leave them there to hatch. Several birds lay their eggs in one heap.

The Sulu Archipelago is inhabited by four groups of people, each with its own language. The use of the term Moro to mean a group of natives of the Philippines or their language is highly incorrect. Moro is merely the Spanish name



SAMAL VINTAS OR SAILING BOATS IN THE SULU SEA

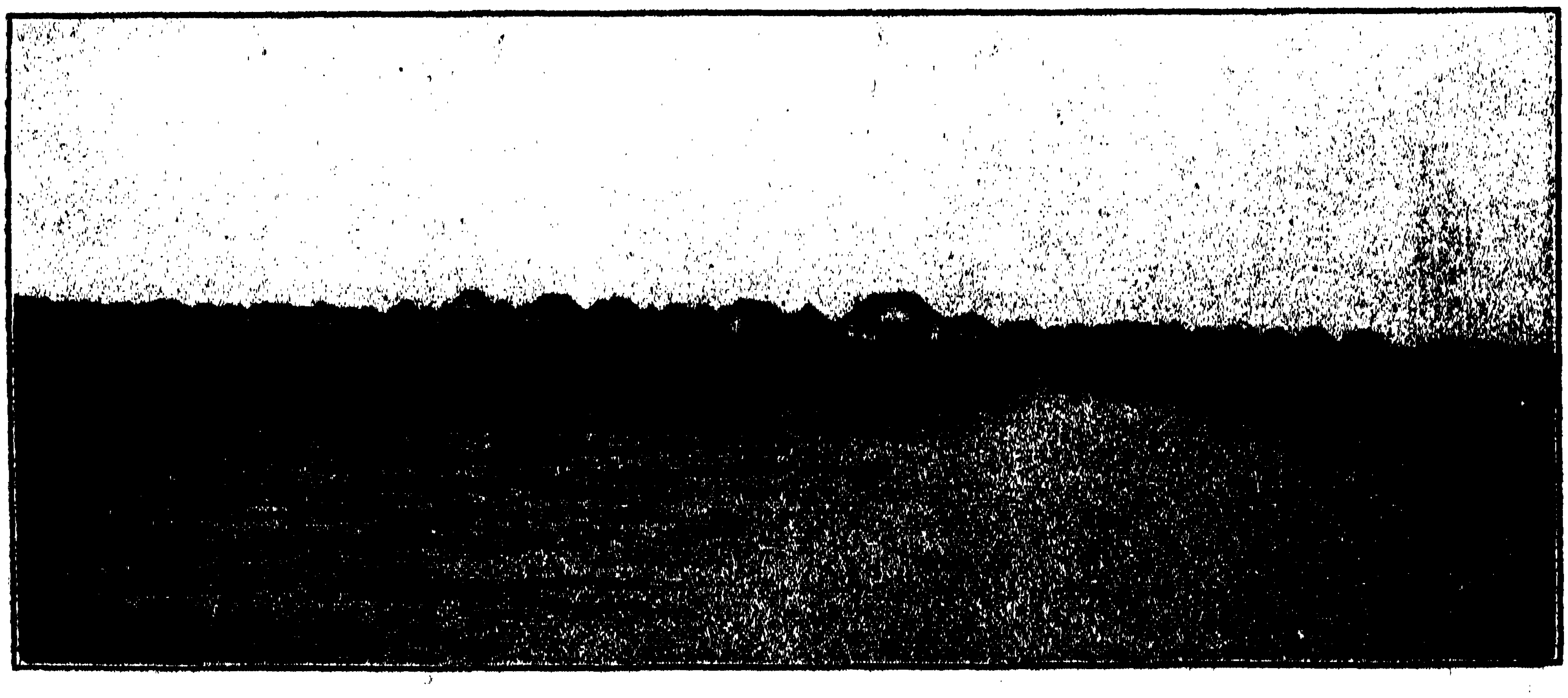


A SAMAL VINTA AT JOLO

THE SAMALS LOVE TO DECORATE THE SAILS OF THEIR BOATS.

for Mohammedan. There never was such a thing as a Moro tribe or Moro language.

The best known of the people of Sulu, and the most important politically, are the people of Jolo and the adjacent islands, who call themselves Tao Sug, or people of the current. Their language is also Tao Sug. They are farmers by occupation, but are the political leaders and the aristocracy of the Archipelago. Formerly Jolo was the great slave market and center for outfitting pirates. As it was the residence of the Sultan of Sulu, its people early gained social and political dominance over those of the rest of the islands.



A SAMAL VILLAGE OUT IN THE LAGOON

SANITARY, GUARDED BY BROAD REEFS, SUCH A LOCATION WAS IDEAL IN THE OLD DAYS WHEN PIRACY WAS THE OCCUPATION OF ALL TAWI TAWI.

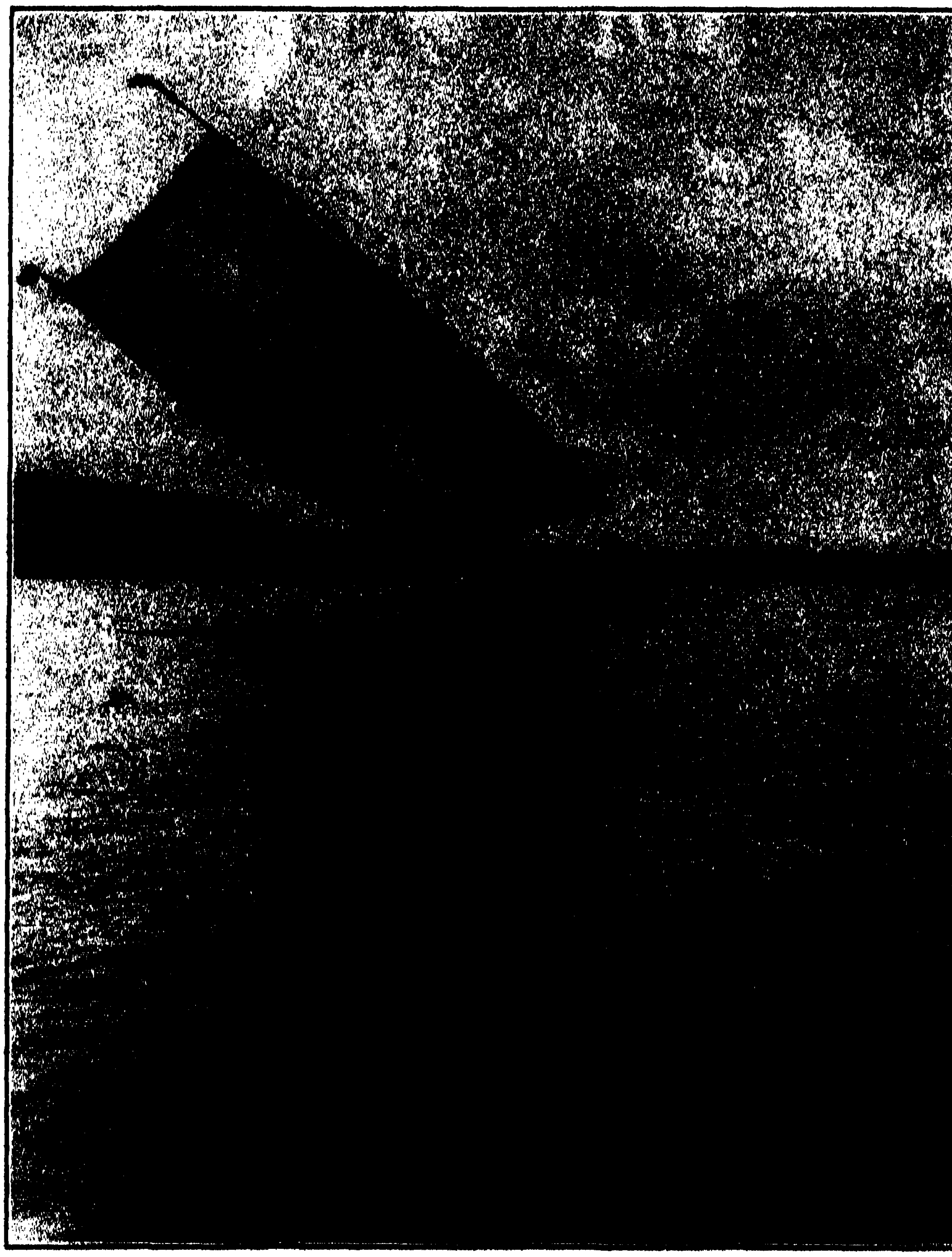
From Siasi southward to Sibutu Passage live the Samals, speaking the Samal tongue. They are also around the coast of Basilan and in Mindanao on the coasts of Zamboanga and Davao provinces. They dwell in greatest number on the small islands clustered about Tawi Tawi and are the boldest and hardiest fishermen and sailors of all the people of the Philippines. Until driven from the seas by the advent of steam gunboats they were noted for their piratical exploits, ravaging the East Indies from the north coast of Luzon to Singapore and Malacca.

A SAMAL CEMETERY AT SIMUNOL, SULU ARCHIPELAGO

The people of the Sibutu group are ordinarily but incorrectly classed with the Samals. They resent this, however, and call themselves Sibutus; their speech is close to Samal, but it a distinct tongue. The Sibutus are identical with the people who inhabit the coast of Borneo around Darvel Bay and northward toward Sandakan. Their language, customs and traditions are the same, and families are divided, part living on the Bornean coast and part among the Sibutu islands. The people are always visiting relatives back and forth on both sides of the artificial boundary line. The Sibutu people are not such fishermen or sea rovers as the Samals.

Each family grows cassava and catches fish for its own consumption. Little or no effort is made to obtain a surplus, since in most cases it could not be sold. The diet of these islanders is very restricted as a rule, as almost no vegetables are produced and very little fruit grown. However, their diet in the past must have been much more restricted, since cassava has not been known to them more than two hundred and fifty years at the most, having been introduced into the Philippines by the Spanish.

The Tao Sug, Samal and Sibutu people are all Mohammedans, and therefore do not eat the meat of the wild pigs that are so plentiful. All these people have grown a few coconuts from time immemorial, in order to furnish them with cooking fat. During the past six



A LIPA FROM SIBUTU

THE SAIL IS SHIFTED TO ANY ANGLE ACCORDING TO THE DIRECTION OF THE WIND.

years, under the guidance of Governor Carl M. Moore, coconut planting has been systematically undertaken upon a comparatively large scale. It will be but a matter of a few more years till all the available land will be in bearing groves of coconuts, and the islanders will all be relatively rich.

In every village a few chickens, goats and half-starved runty cattle are to be seen, but they are never of importance and are rarely eaten.

The village of Sibutu is composed of a straggling line of houses extending along the water front for more than a mile. Owing to the great waves that sweep over the reef during storms the houses are built, with few exceptions, twenty to fifty feet back of the water line. Like the Samals, the Sibutus build over the water wherever it is possible. Few nipa and bamboo houses of the ordinary Christian Filipino type of dwelling are built. Instead the walls are made of hewn boards, a type of house common among the Samals also. Each house is occupied by a number of people; the smallest and poorest shack has two or three couples with their children, while the larger houses may have several dozen inhabitants.

Around and behind the houses are groves of tall old coconut palms, most of them planted without any system. Among the trees behind the houses and huddled into groups, but nevertheless forming an almost continuous broad row, are the village graves. When a

person dies the body is laid in a coffin, which is placed in a very shallow grave. Around the grave rocks or slabs of stone or thick boards of very hard wood are placed and the space within them filled with white beach sand, which may be heaped up till it is several feet deep. The enclosing wooden or stone slabs are often intricately carved in flowing arabesques or have inscriptions written in Arabic characters. Over each grave is placed a more or less elaborately carved and decorated gravestone or wooden column or board. This grave marker is really a conventionalized phallic symbol and indicates the sex of the buried person.

Drinking water is obtained by sinking shallow open wells here and there among the graves, water being found at a depth of fifteen to twenty feet. It is never very plentiful, and in time of prolonged drought is more or less brackish. On some islands the water is so salty as to be undrinkable except by those habituated to it from infancy, and several of the inhabited islands have no drinking water at all unless rain water is caught.

The Sibutu people, like the Samals, are a Malay blend of many of the tribal types found from the Malay Peninsula to Celebes and Jolo, but they are not so conglomerate as the Samals, who had

GOVERNOR CARL MOORE, DATU JAPAAL, AND VILLAGE ELDER
SEATED ON THE GRAVE OF MAKDUM AT TANDU BANAK, SIBUTU. MAKDUM WAS THE FIRST MOHAMMEDAN MISSIONARY TO REACH THE PHILIPPINES.

A GROUP OF BAJAUS AT SITANKAI, SIBUTU ISLANDS
NOTE THE CAUCASIAN FEATURES OF SOME OF THE MEN.

women of every race, white, brown, yellow and black, in their harems. As among all the Filipino people, there is an admixture of Chinese. Datu Japaal, the hereditary ruler of the Sibutus, resembles in everything but color a plump, heavy-set, prosperous Chinese merchant or official. On inquiry I learned that his maternal grandfather was a Chinese merchant on the coast of Borneo, who had married the daughter of the local datu. Japaal himself was born in Borneo while his mother was visiting her relatives there.

Polygamy is not rare, but as a rule most men can not afford to support two wives. Slavery was always mild and is now almost extinct.

According to local tradition, the first Mohammedan missionaries to reach the Philippines landed on Sibutu. They are always spoken of as Arabs, but it is more probable that they were half-breed Arab traders from Johore. The legend states that there were seven brothers, and that the oldest one, named Makdum, remained upon Sibutu, preaching and proselyting, and that he died there. At the barrio of Tandu Banak, already mentioned, there is a grave covered by a very large heap of white sand. The old men of the village insist that this is the grave of Makdum. It is evidently the grave of a man, for buried far down in the sand we found a broken male phallic stone emblem. Personally, I have no doubt that it is just what the villagers say, the place where Makdum was buried five hundred years ago.

In the southern part of the village of Sibutu, just above high-tide mark, is an old stone cotta or fort, evidently built a very long time ago and now in a ruinous condition. On one corner next the sea is a gigantic banyan tree, the only one on the island and the largest in the Philippines. With its many trunks and innumerable aerial roots sprawled all over the old coral walls of the fort, it was evidently planted generations ago. The people believe that the Kukuk, or spirit of the banyan tree, lures away children.

Formerly the Sibutus paid great heed to witch doctors, but nowadays they will have nothing to do with them. About

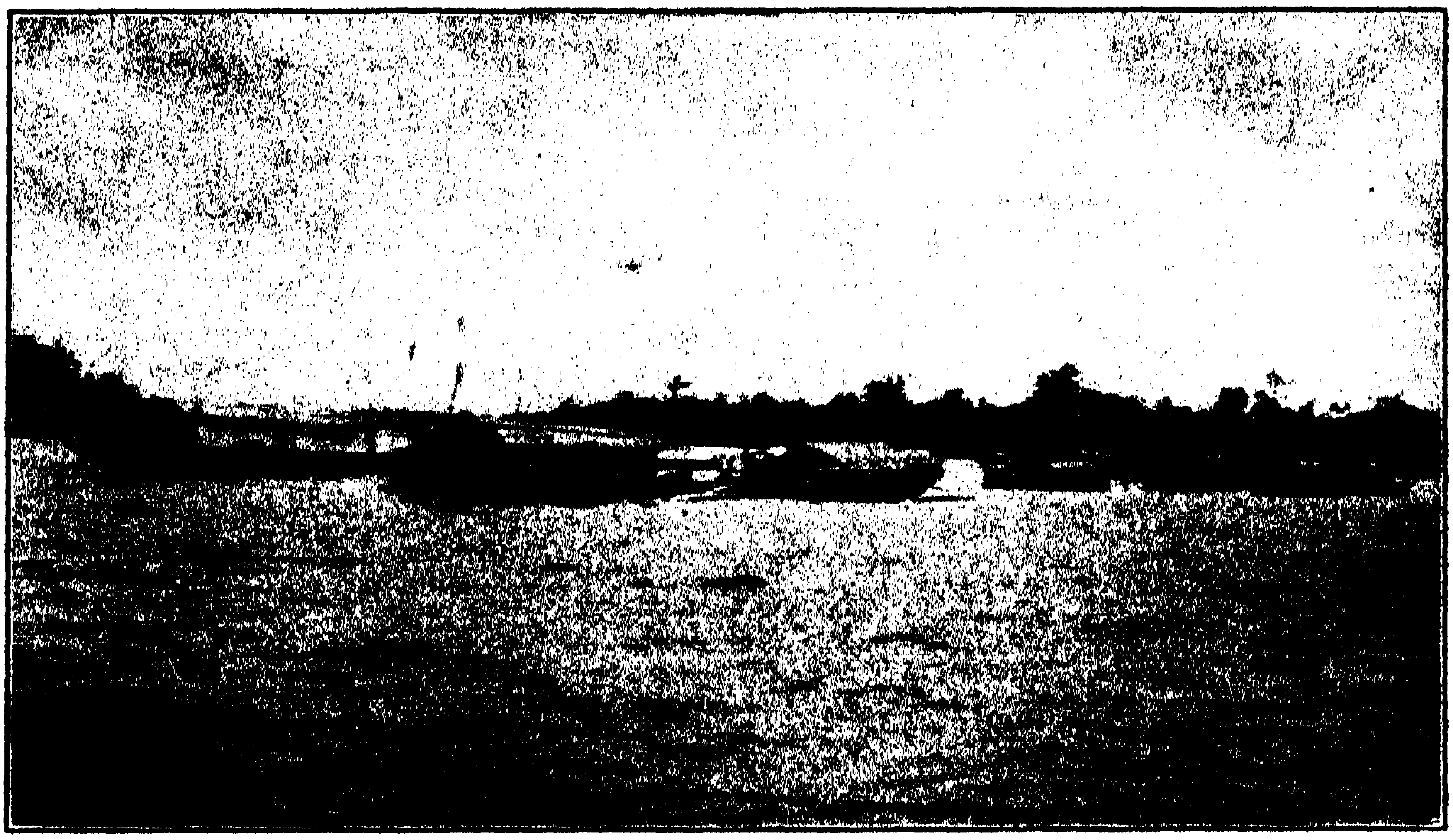
1890 there was a great epidemic of cholera and Mahilan, an old woman with a reputation as a jinn or witch doctor, pretended to be able to exorcise the disease. With some of her followers she went to the mosque and held prayers. Then her deluded disciples carried her about the village so that she could repeat her incantations and charms at the houses of all the afflicted. While engaged in this awe-inspiring and laudable task she herself was taken sick and died of cholera before she could complete the tour of the village. This cured the people of their faith in jinn doctors.

Life in a village like Sibutu flows on evenly without rush or worry and demonstrates that much of our alleged progress and complex civilization is either unnecessary or else leads nowhere. There are no factories or stores, hotels or restaurants, streets or roads, newspapers or movies, telephones or radio, police or clergy, bridge parties or country clubs, lawyers or prostitutes or any of the other concomitants of modern city life, some of which are necessary to any considerable group of people, but others are certainly not. There is no booze problem, for the Koran forbids alcoholics and Mohammedans apparently live more closely after their religious precepts than do Christians.

At rare intervals a few tourists may pass. To them such villages and islands seem full of glamor, the home of romance and beauty, full of the lure of the unknown. The half-naked villagers, decorated rather than clothed in the brilliantly colored and lavishly gaudy garments dear to the Mohammedan Malay, add to the attraction and mystery.

The casual visitor, surrounded by the luxury of a steamer, gazes at the half-concealed nipa-bamboo cottages ashore and sighs for an idyllic life in a palm-embowered love-nest. Lost in a maze of mush and sentimentalism, tamely married army wives, plump and long past the bloom of youth, or well-endowed old-maid school teachers yearning for life, indulge in vague dreams of love with a thrilling and satisfying soul companion who carries them away from the prosaic world to dwell beneath the dense canopy of a coconut grove beside the jewel-like beauty of a coral reef. There the perfume of waxy-white frangipanni and seductively glowing orchids, the enchanting song of great golden orioles

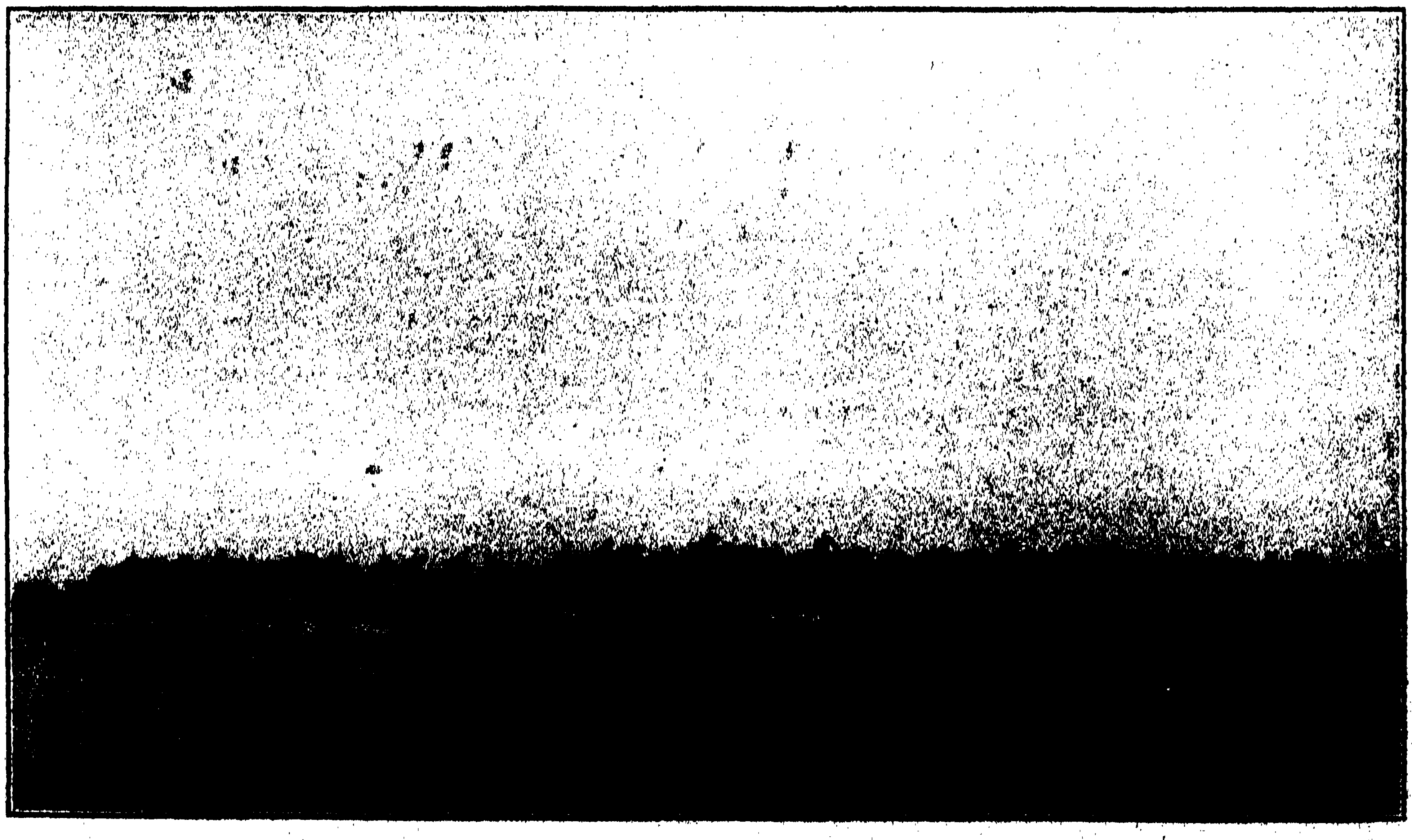
A BAJAU HOUSE AT SITANKAI, SIBUTU ISLANDS



A BAJAU VILLAGE OF HOUSE-BOATS
TUMINDAO, SIBUTU ISLANDS.

and voluptuous cooing of huge flower-like fruit pigeons would lull their senses, while they fed on the honey-dew of kisses and love.

As a matter of fact these dreamers, deprived of ice and a rich varied diet, cut off from bridge and teas, could not stand existence on one of those lone coral isles. Only the naturalist or one rich in inner resources and therefore not afraid to be alone with himself can enjoy an extended stay in such places. Even among such choice spirits it is only a few who can overlook the frequently monotonous diet and insufficient water supply, and who can successfully resist intestinal infections and parasites; none but these can really enjoy a prolonged



SITANKAI, SIBUTU ISLANDS
THE SOUTHERNMOST TOWN OF THE PHILIPPINES.

stay on these "isles of the coral-studded sea."

There is a school at Sibutu, with Christian Filipino teachers, where Mohammedan boys and girls are taught things as unreal to them and as disassociated from their present and future lives as a knowledge of non-Euclidean geometry is to a garbage collector. I do not mean to say that these children should not go to school, but I do say that the present curriculum is not one adapted to their needs. In general it trains them away from the life about them without substituting anything valuable to replace what they have lost. They can not all be teachers and apparently that is all their schooling fits them to be.

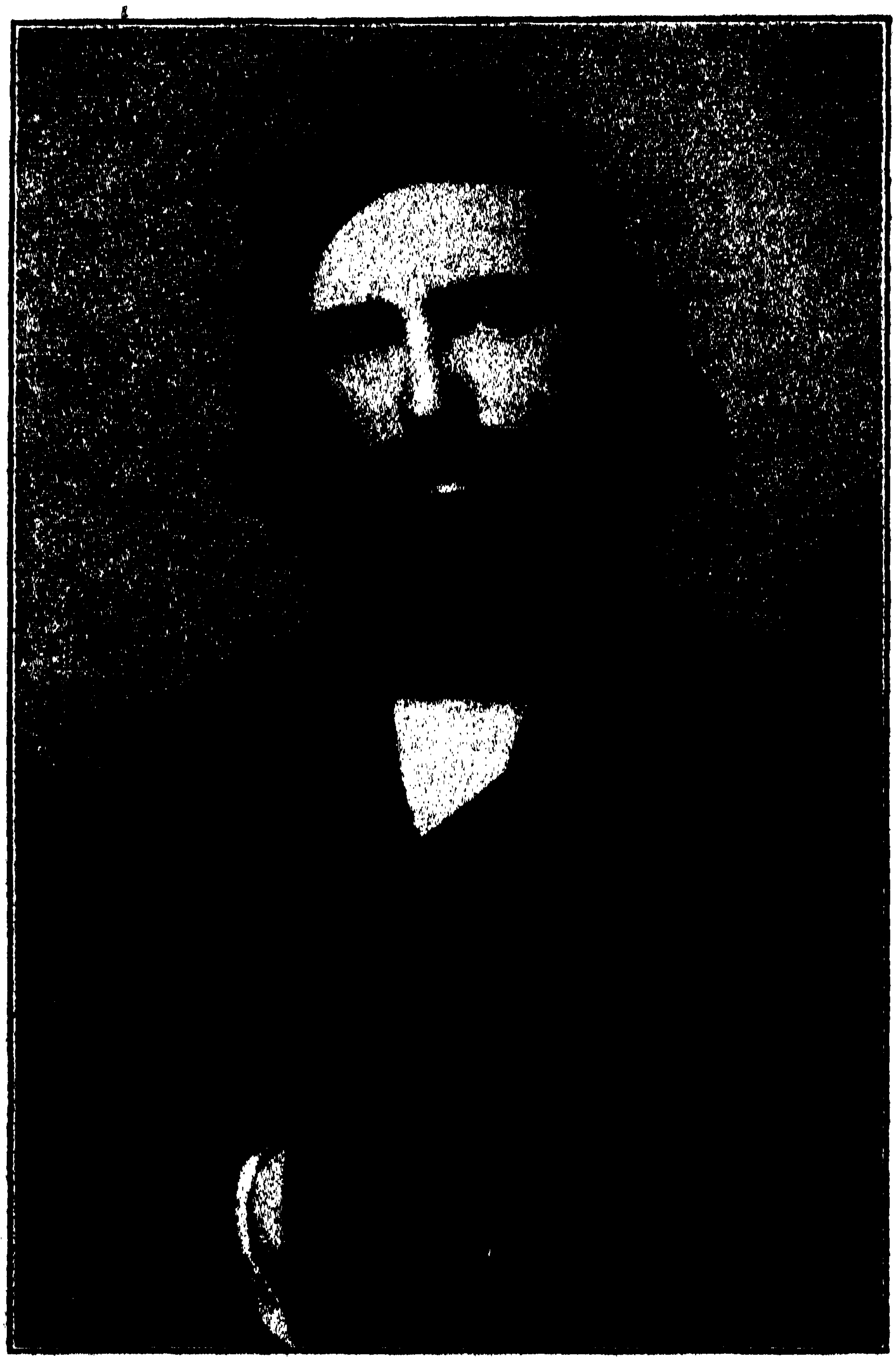
The Sibutu Islands are the Philippine headquarters of those strange sea-dwellers known as Bajaus by the Samals and called Sitankai in the Sibutu language. They are widely known as sea gypsies and are true nomads of the sea. The Bajaus are a comparatively tall lean Indonesian pagan people. They are found only along the coasts of Borneo, Celebes and the Sibutu Islands, although a few venture now and then as far north as the Tawi Tawi group. They never live on land but are born, live and die on the sea, making their homes in rude houseboats. These are moored in clusters or groups which might be termed villages, hidden in some sheltered nook and protected from storms and waves. In addition to their houseboats, the Bajaus have lipas or bancas which they use for fishing or going about while engaged in their everyday affairs. The Bajaus live exclusively by fishing and are very skilful when one considers the crude methods and appliances at their command.

The Mongol strains in the Malay race seem to be little evident in the Bajaus, and the Indonesian element seems to be stronger than in any other inhabitants of the Philippines. Many of them are European in appearance except in color, with regular Caucasian features, and are tall and well built. Unlike the Mohammedans and Christians, both men and women wear the hair long. Little is known of their language or customs. Unlike their land-dwelling neighbors, they apparently have no domestic arts such as weaving and pottery making. Their food is almost exclusively fish and cassava, the last purchased from their land-dwelling neighbors.

Rumor blackens their religion, morals and social organization. Incest is said to be very common. Such reports must be largely discounted, but it is evident that they have no very elevated standards. When people are huddled together permanently into very confined quarters, things are prone to happen which would be very unlikely to occur under different living conditions

Each little group of Bajaus seems to be largely independent of all others. The Bajaus are a feeble and comparatively timid people, in former days defenseless against their piratical neighbors and unable to develop any numerical strength because of their mode of living. They have been able to survive as a definite tribe because of their extreme poverty, which offered nothing to the Samal pirates. Then, too, their habit of hiding in small groups along the shores of sequestered bays on uninhabited islands, often where strong currents made navigation difficult for sailboats during much of the year, has been an important factor in their maintenance.

The only land with which the Bajaus have any permanent relation is a tiny island which the Sibutu people long ago named after them. From time immemorial it has been their burial ground, and accordingly the Sibutus named it Sitankai, which is what they call the Bajaus. On this minute island, which is only about ten hectares in area, is the town of Sitankai, which has the distinction of being the southernmost town in the Philippines. It is of much importance for its commercial fisheries.



ALBRECHT VON GRAEFE (1828–70)

ALBRECHT VON GRAEFE

THE FOUNDER OF MODERN OPHTHALMOLOGY (1828–1870)

By Dr. THEODORE KOPPÁNYI
SYRACUSE UNIVERSITY

One of the greatest of the great scientists and benefactors of suffering humanity was Albrecht von Graefe, a man of whom his native country can justly be proud. But science is international and his work is a blessing to all mankind. Nowhere should the one hundredth anniversary of his birth pass unnoticed.

Albrecht von Graefe was the distinguished son of a distinguished father. Karl Ferdinand von Graefe (1787–1840) was professor of surgery at the University of Berlin and eminently successful in the practice of general and ophthalmic surgery. His name is inseparably associated with the revival of plastic surgery, especially rhinoplasty, *i.e.*, an operation for forming a nose from the skin of the forehead. He died rather suddenly at Hanover, whither he had been called to operate on the crown prince.

Albrecht von Graefe (born May 22, 1828, at Berlin) received at home a good early training. His father's death did not interfere with his education, and under the guidance of his high-spirited mother he spent a happy childhood in their beautiful home in the Berlin "Tiergarten." Maturing early, he graduated at the age of fifteen from the French gymnasium in Berlin.

Believers in the heredity of intellectual faculties could point to the von Graefes as one of the numerous examples where illustrious fathers did not have mediocre or obscure children. And protagonists of the theory (so ably criticized by Professor Jennings) that the relatively advanced age of the father has a beneficial influence upon the general ability of the offspring could emphasize the fact that Karl Ferdinand von Graefe was forty years old when his son was born.

Even in the secondary school, young Albrecht showed preference for mathematics and natural sciences, and these disciplines did not cease to attract him while a student or graduate in medicine.

One of the youngest students ever entering a medical school, von Graefe studied at Berlin under such men as Johannes Muller and Rudolf Virchow. At the age of twenty he received his M.D. degree. The financial independence of his family was very advantageous for the young physician, for he was able to set out for a long journey, his scientific "Wanderjahre." In Prague he first came into contact with ophthalmology as an independent discipline, represented there by Professor Arlt. This great teacher was largely responsible for the fact that von Graefe chose ophthalmology as his main field of interest. From Prague he went to Paris and associated himself with many excellent eye specialists, and, above all, with the greatest experimental physiologist of France, Claude Bernard. In Vienna, "the birthplace of ophthalmology," he worked with the two Jaegers, father and son. Again it was his good fortune that his Viennese sojourn occurred during the "golden age" of the medical school of that university. London was the next and last stop in his itinerary, where he studied with Bowman and Critchett.

Upon his return to Berlin, von Graefe founded an eye clinic, a model institution at that time. His alma mater offered him an associate professorship in 1856 and he had to wait ten years before he was made full professor and director of an independent university institute for ophthalmology. In the meanwhile, supported by his old teacher and friend Arlt and the Hollander Donders, he started a periodical in ophthalmology, which is still the leading German publication in that branch.

Von Graefe was a man of delicate health and suffered much and heroically from tuberculosis of the lungs. Fortunately, he was unusually happy in his family life and the self-sacrifice of his beloved "little bride," the Countess Anna Knuth, greatly increased his working capacity. But when his wife developed pneumonia and became an invalid for the rest of her life and two of their children died, his own condition rapidly grew worse, and only four years after his appointment as full professor he was cut off prematurely by death (August 20, 1870, at Berlin). He continued to work until almost the day of his death. He had to use morphine to enable him to lecture and to operate. On the night of August 19 his condition became critical; he felt that the end was approaching. He wanted to see the daybreak. Like Goethe, he wanted "Licht, mehr Licht." On the next morning he fell asleep in his armchair and did not waken.

Von Graefe was a man of strong liberal and democratic tendencies and a humanitarian in the truest sense of the word. Wherever he went people flocked to him, and even during his summer vacations he was always ready to help the sick, be he rich or poor.

The contributions of Albrecht von Graefe to ophthalmology are so numerous and some of them so technical that we can hardly do more than mention some of his epoch-making innovations. The eye-mirror, or ophthalmoscope, an instrument invented by the great physicist, Helmholtz, in 1851, made the interior of the eye accessible to investigation. It is based on the principle that a beam of light reflected from a mirror is thrown into the eye through the pupil and upon the fundus of the eye, and a reflection of this light is received through a hole in the mirror into the observer's eye; and thus one obtains an image of the fundus of the eye examined. Von Graefe recognized at once the importance of this discovery in the diagnosis of the diseases of the eye. In von Graefe and his friend Donders' hands, the eye-mirror soon became the instrument which disclosed to us the abnormal changes of the inner eye membranes and their blood vessels and nerves. It enabled the medical profession to study these processes, recognize their early appearance, and thus make early and rational treatment possible. It was found subsequently that not only diseases of the eye, but involvements of the nervous system and other organs also produce changes in the eye ground and the eye-mirror was extended to other fields in its application. In this field, too, von Graefe made a fundamental discovery. He observed that one of the early symptoms of increased intracranial pressure was a change in the characteristic appearance of the optic cup. This is very important in the early recognition of the existence of brain tumor. The eye-mirror thus became indispensable in the fight to combat disease, and it was chiefly through von Graefe that it created a revolution in ophthalmology, and that it has, in more than one sense, thrown light into regions that were formerly completely dark.

If the crystalline lens becomes opaque, seeing images is no longer possible. Several surgeons succeeded in removing the opaque lens from the eye

and restored vision. But the hazards of this operation were great, and very often eyes were lost, due to the suppuration of the transparent outer coat of the eye, the cornea. Von Graefe thought that this suppuration was due to the great gaping of the incision, and that the lips of the wound were not properly applied to one another. He developed a new and better technique, which made the removal of the lens *a safe operation.* About the same time Lister made his famous discovery of germs as the cause of post-operative suppurations and infections. Von Graefe saw Lister personally, was deeply impressed by the British discovery and adapted the antiseptic procedure to operations on the eye. Thus he taught his colleagues how to be doubly sure to avoid infection following the removal of the lens and in other eye operations. He also advanced operative technique by inventing a number of surgical instruments, especially his famous linear knife, which are as widely used to-day as shortly after von Graefe's introducing them.

Von Graefe introduced silver nitrate for the treatment of suppurative conjunctivitis, a treatment eminently effective to this day. His interesting study of the physiology of the eye muscles led him to introduce various surgical methods for correction of squint.

Von Graefe's sign, an important diagnostic symptom, is generally used in physical examination of individuals in whom exophthalmic goiter is suspected. This sign consists of the individual's inability to lower the upper lid when told to look at the floor.

These contributions alone would insure von Graefe's claim to immortality, and yet his fame chiefly rests on another epoch-making discovery. This concerns the discovery of the nature and cure of a terrible eye affliction called *glaucoma.* This disease, which manifests itself by disturbances of vision accompanied by severe pains, resulted inevitably in blindness, and even then the tribulations of the patient did not end, for he was still tortured by pain. Von Graefe made a most profound study of the disease and came to the conclusion that all the symptoms of the glaucoma were due to one single fact, the increase of the pressure within the eyeball. He thought that the remedy must consist of a lowering of the pressure. That he achieved by removing a piece of the iris. The result proved the correctness of von Graefe's assumption. Thousands of people, all over the world, are now saved every year from blindness through von Graefe's iridectomy.

Von Graefe's early training in the fundamental exact sciences was surely one of the chief factors which made his great discoveries possible. It made ophthalmology perhaps the most exact of the medical disciplines.

Von Graefe died young, scarcely at his prime, but his work was finished. He had fought well against the Powers of Darkness.

GOOD HOUSING FOR FAMILIES OF MODEST MEANS

By Dr. JAMES FORD
HARVARD UNIVERSITY

PROGRESS is impossible unless each generation is provided with conditions of living superior to those enjoyed by preceding generations. Our chief obligation as citizens is to see to it that our children may have a better start in life than we had.

Man is deeply influenced by his environment. The best of human stock may be injured and its development thwarted by adverse conditions. A farm crop depends not merely upon well-selected seed, but also upon proper conditions of cultivation, soil, climate and weather. Similarly human personality and character are the result of the play of environment upon native individuality.

Our immediate problem is to find out how good housing can be brought within the reach of families of modest means, which constitute the majority of our population. It should be recognized that most families will be compelled to live in old houses. If the average life of a house is from one third to one half of a century, most persons can not live in new dwellings. So our first question is to ask how old houses can be made better.

The obvious answer is that there should be good building laws, health laws and housing laws, wisely framed by citizens who have practical knowledge of the subject of housing and who though cognizant of practical difficulties have standards that are high and sound. Such laws must be enforced by wise and practical citizens whose standards are also high. As no law is self-enforcing, it is necessary to have in each city a body of local citizens to make a continuous survey of housing needs and standards and to lend public officials their moral support and assistance. Philadelphia, New York City, Brooklyn, Pittsburgh and Cincinnati have such organizations, but in most other cities there is no such medium of community service. Standards of housing legislation and enforcement are therefore relatively low.

The next essential is to have agencies for the education of tenants and landlords which can help the latter to see that the ownership of rentable property is a form of trusteeship in the service of the community and can help tenants to recognize their responsibilities and privileges as parents and homemakers and as neighbors and citizens. In this field, again, Philadelphia is peculiarly fortunate in having the Octavia Hill Association, which has done outstanding work through its ownership of old remodeled properties and through its rent-collecting agency. This service to both home owners and tenants should, however, be universally available, since no citizen, whether owner or tenant, can, without help, keep fully informed of the most economical and most effective ways of making improvements in his own property. In rural regions admirable service is being performed through the extension departments of state colleges.

The organization of local volunteer Better Homes in America committees is a valuable supplement to these other forms of service, because such committees are made up of leading local citizens representing the various civic agencies of the community. A great deal of advice and help on local problems is

available through the civic organizations which are represented on the local committee, and virtually the whole population is reached through the lectures, discussions, contests and demonstrations which are arranged. By adapting their programs to meet the most urgent of local needs as they find them, and by varying their programs from year to year as new problems appear or old ones are solved, they contribute greatly to the leveling up of prevailing standards.

By demonstrating to the community the best examples of effective reconditioning or remodeling of old premises they prove that notable improvements can be accomplished at a cost that is relatively low. They can also stimulate the local public to make improvements on their premises through home improvement contests, kitchen contests, living-room contests, home garden contests or neighborhood improvement contests. Contests have appeal both to man's competitive instincts and to home and community pride. Hence notable progress in the bettering of local standards for families of modest means may be made in any given year.

Families that are relatively poor have ordinarily been condemned to live in the cast-off houses of the families next above them in the economic scale. But as all our cities are growing through births and immigration and through migration from less populous districts, new houses have to be built each year to accommodate this increase, as well as to replace dwellings eliminated by obsolescence and by the extension of business and industrial areas. The housing shortage caused by the war has been largely met in most American cities so far as homes for the well-to-do are concerned, for the obvious reason that larger profits for speculative building are possible through catering to these classes first.

The question may properly be raised: would it not be possible to provide good new housing within the reach of wage-earning families? The division of building and housing of the Department of Commerce estimates that under ordinary conditions a wage-earning family can afford to spend for its home a sum equal to from two to two and one half times its annual income. Thus, a family whose members regularly earn $2,000 a year could afford a house which, with its lot, would cost from $4,000 to $5,000; and a family earning $1,500 a year could afford a house which, with its lot, would cost from $3,000 to $4,250.

Can unskilled wage-earners also be reached? In the south this question is already answered in the affirmative, for labor and construction costs are low and cellars and central heating equipment do not have to be provided. The answer is more difficult in the north because of higher land, labor and construction costs, and also because the family that is willing to live in a three-room flat would scorn to live in a three-room house. Yet I am confident that within the coming generation we shall be able to solve this problem, too. There are several points of attack, and some research by specialists will be necessary before an entirely satisfactory solution of universal applicability will be found.

The first essential is to discover the most economical house plans that are consistent with good architectural design, and to make these plans accessible to operative builders and to individual home builders. A square house is ordinarily the most economical as to material, the cheapest to heat and the easiest to furnish; but most plans for square houses are hideous from the point of view of design, and our unfortunate practices in the subdivision of urban land practically preclude this type of house except in the remote outskirts of our cities. The Architects' Small House Service Bureau, established by the American Institute of Architects, pro-

vides plans at low cost for persons who would not ordinarily have access to the services of good architects, and is performing excellent service in this field. It is, however, confining its activities to the detached single-family house. In general, our best architects have not been interested in solving the problem of single-family housing, semi-detached housing or row or group housing for the wage-earning population. There is an immense field for public service here. The problem probably can not be met except through endowment funds, for experimentation is costly and seldom lucrative.

The next essential is judicious experimentation in standardization. A tailor-made suit costs about twice as much as a ready-made suit. Similarly when houses are "custom" made, their unit costs are high. Herbert Hoover, with characteristic vision, has, through the division of simplified practice of the Department of Commerce, succeeded in making standardized units for building materials and equipment generally accessible to the American public at relatively low unit costs.

It is necessary to make standard house plans of economical, efficient and convenient type, universally accessible. With such plans there should be a wide variety of exterior designs, each artistic in character, so that a whole community may be built with the use of not more than a half dozen standard floor plans but with varied exteriors. Thus monotony would be avoided and the economic advantages would be possible which come from buying standard materials by the carload and from using teams of laborers who are familiar with the plan and who can, therefore, build with a minimum loss of time between operations. When whole communities can be built from satisfactory standard plans and standardized materials, the unit cost will be at a minimum for services of architect, contractor, engineer, labor, legal advice, financing, land and utilities. Hence if good new housing is already within the reach of skilled labor, it is a safe presumption that by these means good new housing can be brought within the reach of unskilled wage-earners as well.

There are several other measures which can be applied to reduce the cost of housing. Some of these are immediately applicable, and others would take a generation or more to get established. An example of the latter toward which we should definitely move is industrial decentralization. If factories can be moved out from the hearts of our cities to remote suburbs or the open country, it will be possible to plan and build whole villages of wage-earners' homes, applying the best principles of architecture, city planning and landscape gardening to the project. This program is much more possible of accomplishment now than it was two decades ago, due to the tremendous development of superpower and of power transmission, and should be seriously considered by all far-sighted groups in the field of town planning and housing. For with the necessary power available and with land purchasable at its agricultural value and with the relatively low tax rates of rural districts and the possibilities of spur track connections with railroads, the decentralization of industry becomes a practical possibility. Residential decentralization should accompany it. Of course, such a program would involve a better development of labor exchanges and adequate opportunities for recreation in the new garden cities. But there is sufficient knowledge now at hand to meet all of these needs and to provide cultural opportunities and wholesome indoor and outdoor recreation as well as private, secluded, beautiful homes for all industrial workers. We should be content with nothing but the best. The best

is now practically within reach, and by far-seeing social service the amenities of life can be afforded to the industrial worker and his family.

Other devices for reducing housing costs include measures for city planning and zoning, for cheap and easy money for house building and home acquisition and for cooperative ownership. English experiments with copartnership housing have demonstrated the possibility of providing harmoniously developed communities through garden suburbs for wage-earners, and have shown that cooperative ownership is better than private ownership for industrial workers in certain types of communities, as it gives them freedom of movement and makes the disposal of their properties relatively easy in case they wish to move elsewhere. At the same time there are no losses from arrears in rent in cooperative colonies because the shares of stock can be seized to meet any such delinquencies. There are no losses from vacancies because each shareholder in the cooperative group will wish to bring his friends to the colony, and in the case of a vacancy, they are all, therefore, in a sense renting agents. Moreover, upkeep costs are at a minimum because each tenant has every incentive to keep his own place in repair. Copartnership housing can not be experimented with profitably, however, at this time and will need much more study to adapt it to American conditions.

Town planning can reduce housing costs for residential quarters first by making all of the outskirts of the city accessible through direct radial or arterial traffic routes. If suburban land is accessible in all directions from the city, there will be more owners ready to sell, and the cost of land per lot will be correspondingly low. For it is scarcity of land of any given type that makes land costs relatively high. Broad arterial streets connecting centers and sub-centers also facilitate rapid and cheap transit and thus make it possible for "downtown" workers to live in private residences within a half hour's ride of their place of work. It should be the inalienable right of every free-born American to live in a home of his own within easy access to his place of work, and no man should be condemned to be a straphanger for more than one hour per day. The decentralization of industry should, however, ultimately make possible for every industrial worker a home within walking distance of his place of work.

Town planning can also facilitate improved housing through judicious subdivision of blocks and lots in residential areas. In general, in our American cities lots are too narrow and too deep. Winding streets in protected residential areas may be narrow and relatively inexpensive, ornamented at slight cost with grass strips and trees, and in this way provide attractive vistas for every home.

Zoning in cities makes possible the separation of industrial and business areas from residential areas, and can thus protect homes from the dust, noise, fire-risk and chemical fumes of the factories. The trucking to and from factories can be kept off residential streets, thus reducing accident dangers. Zoning also prevents the beauty of residential streets from being marred by the ugly outline of the factories.

Through zoning it is now possible also to keep apartment houses out of single-family-house neighborhoods, thus reducing the volume of traffic on residential streets and preventing huge multiple dwellings from overshadowing their neighbors. Neighborhood shops can be localized at strategic sub-centers accessible to the residential neighborhood, and thus nothing need mar the charm of the homes of our citizens of modest means.

Cheap money for home building and home acquisition is necessary if home

ownership is to be rendered universally possible. Of the importance of home ownership for most families there can be little question, because it gives all members of the household a common interest of a vital sort, an opportunity for common sacrifice for a worthy end, an opportunity for common self-expression and family pride, and, most important of all, a stake in the community and recognition of the duties and the privileges of citizenship.

The most important agency for coping with this problem is the building and loan association. But some such associations have tended to favor the investor against the borrower by charging relatively high rates of interest for money borrowed for home acquisition or home construction. If borrowers could secure first mortgages at 6 per cent. interest, as they do in the cooperative banks in Massachusetts, and second mortgages at 7 or 8 per cent. without the payment of premiums, home ownership would be encouraged.

Other countries provide government credit for house building, subject to plan supervision by the government, but we have probably rightly assumed in America that that should be looked upon as a last resort and that our problem should and can be met through private agencies. There are some evidences that second mortgage loan companies can be established in this country to lend money on residential property at interest rates as low as 7 per cent. Study of these ventures might lead to a considerable extension of this practice wherever it may prove practicable. Easier terms of amortization of loans may prove necessary for wage-earners, particularly for those who are unskilled. A lengthening of the period of amortization from fifteen to twenty years might bring home ownership within the reach of unskilled workers much more generally than is now the case, and still might be consistent with conservative and safe mortgage investment on the part of the lenders.

Labor costs in small house construction, as has already been pointed out, can be reduced by standardization, which would reduce the loss of time involved in waiting for materials or instructions. Large scale construction also makes possible continuous work for gangs of carpenters, plasterers, plumbers, and others, who can move from house to house on a predetermined route. It is likely that during the next generation experiments in house construction will lead to the common use of new processes of fitting together houses from mill-made parts in each of several different materials, and thus make possible the use in large part of unskilled labor in house construction. A more general use of winter construction, as suggested by the U. S. Department of Commerce, will have the advantage of keeping the building trades active throughout the year and of making it possible to build houses with relatively little use of overtime labor and thus with slight expenditure at overtime rates.

Carrying costs for home owners, once they have moved into their new homes, can be reduced through building homes of sound construction. The jerry-built house may be cheap to acquire, but is costly to carry, as it is continuously getting out of repair. Easy interest and amortization rates have already been mentioned, and the low carrying costs of cooperative ownership have been discussed. One remaining possibility is the reduction of taxation on improvements, or even the removal of taxes on homes. I am not prepared to advocate the latter, in spite of New York's experience with it, but it would be worth while to study this subject carefully. It would also be well to study the experience of Pittsburgh and other cities in progres-

sive reduction of taxation upon improvements to see if it does not indicate an important social policy for the promotion of home building and home ownership.

Where houses are well built and of good design and where community standards of city planning and neighborhood upkeep are high, there will be an actual appreciation of land values, which in turn will increase the borrowing capacity of owners and afford them an opportunity for a substantial profit when they dispose of their homes and move to new quarters. Community values and community reputation are, of course, enhanced by good architecture, good construction and community planning.

PICK-AXE SCIENTISTS

By Dr. WALTER EARL SPAHR
DEPARTMENT OF ECONOMICS, NEW YORK UNIVERSITY

In a recent address before the Wharton School Alumni Society Mr. John Hays Hammond took occasion to comment very pointedly upon the great, if not startling, advances made in recent years in the fields of the pure sciences, such as physics, chemistry, astronomy and mineralogy, in contrast to the lagging scientific developments in the so-called social science fields. Referring particularly to mining, he pointed out that fifty years ago the prospector did his prospecting with his ever-present pick. To-day the most advanced and refined resources of modern science are utilized; the certainties of scientific methods are substituted for the chance results of the man with his pick; the trained geologist and even the radio serve to reduce chance to a minimum. The social scientists, however, have hardly advanced beyond the pick-axe stage; their methods doubtless are little advanced beyond the methods employed by the exact scientists in medieval times, and by implication, Mr. Hammond dubbed the latter "pick-axe scientists." With his observations it is reasonably certain that competent scientists of both fields agree.

In the fields of exact science, both pure and applied, the modern developments are a source of daily wonder. Starting from small beginnings characterized by endless experiments in what to-day are simple fundamentals, these scientists have worked slowly and painfully throughout the ages. An outstanding discovery in a century would serve as a stepping-stone and guide for the next scientist who, with the impetus of this start, could work more rapidly and more effectively than his predecessors. Each discovery, suggestive in its implications, would beget others. The effect was cumulative until a mere generation would witness an epoch-making discovery, then a decade, then a single year, and now they come so rapidly that we are left bewildered. We no longer attempt to keep abreast of the developments; rather we merely trust the scientist to provide us with anything that fancy might suggest.

The world's confidence in these scientists is evidenced by the huge industrial laboratories established by our leading and foresighted industrialists, by the fact that they sponsor and finance lavishly not alone the applied but the pure scientist, by the fact that they employ the best scientists and let them work without restrictions, by the fact that leading philanthropists do not hesitate

to endow chairs, establish laboratories and build science buildings whenever needed and almost without question. Business men, philanthropists and governments show no hesitation in furthering the cause of the exact sciences; they know the results will more than justify the outlay; they know that the greatest contributions to modern progress have come from these sources. These facts are no longer questioned by those competent to appraise the situation.

With respect to the contributions which the social scientists have made to human progress it is agreed by those well aware of the true status of affairs that their contributions pale into insignificance when compared with the contributions of the exact scientists. It is doubtful if the social sciences are little more than medieval in dealing with political, economic and social problems.

The principles of scientific method as applied in the exact sciences are very simple, although the technique of applying them has long since grown so complex that it is comprehensible only to the highly trained mind. Simple as these fundamental principles are, the social scientists can hardly be said to approach within even a respectable distance of them.

One of the most elementary and cardinal principles of the exact scientist is to gather his evidence through direct observations made while conducting experiments. The evidence upon which the social scientist relies is almost altogether indirect; there is very little, relatively, which he observes directly, since his problems are so widely diffused through both time and space that he must gather up as many observations of others as possible and from such uncertain evidence draw what generalizations he may. From experimentation, as conducted in a laboratory, he is practically excluded. No exact scientist, for a moment, would accept as reliable evidence the very best evidence available to the social scientist.

The exact scientist insists that the observations of experiments be recorded by the observer at once in an exact, precise method, which indicates in detail how the experiments and observations were made and the conclusions deduced. Few indeed are the social scientists who record their observations at once. Instead they rely upon memory, which is fickle, selective and unreliable, and which at the best is based upon their own individual and single observation, and which of course can not yield scientific conclusions. Yet the social scientist usually makes it a point to advertise conclusions based upon his direct observations, often not realizing that it requires many direct observations of several persons working independently to yield scientific conclusions. Aside from his few direct observations most of his evidence is composed of the observations of others, and such evidence no exact scientist could accept and still call himself a scientist.

The exact scientist will not claim that he can draw scientific conclusions so long as competent fellow scientists disagree as to the facts involved, while the social scientist is not at all deterred by what often appear to him to be the pedantic standards set up as the requisites for scientific truth. He relies upon a few indirect sources and occasionally upon a single bit of indirect evidence, failing to observe that at the best his evidence is but a presumption more or less strong, not an established fact.

The exact scientist has as tools exact formulae meaning the same thing to all scientists. The social scientist has few such formulae in his possession and as a result can not present his conclusions in such brief, concise form, and always flirts with inaccuracy and approximation, and is certain to be misunderstood in some respects.

A science to fulfil its functions must enable the scientist not only to classify, analyze and generalize his data but also to forecast. We are quite accustomed to the exact forecasts of the astronomers and of the other exact scientists and recognize quite well that the one thing that the social scientists can not do is forecast. A science is at its best when it enables human beings to forecast events and in this respect the social sciences have failed dismally. Indeed these very shortcomings have caused some thoughtful persons to insist that the social sciences are really not sciences at all. It is also interesting to note the paradoxical fact that could the social scientists really learn to predict, the predictions would defeat themselves in those cases in which the masses would wish to take advantage of the forecasts. Once the populace learned to rely upon a social prediction, social foresight would discount the prediction at once and nullify the prediction. This is the reason why there never can be a genuine barometer of business conditions; as soon as the masses come to believe that such a barometer has been devised it will be defeated at once by the immediate discount of the prediction. It appears, as a result, that forecasting of price levels, etc., is an eternal problem and always doomed to failure in some degree.

The social sciences, it must be observed, are not characterized by truly scientific methods in the most exact sense. Rather the common methods are more or less irrational ones. We settle issues by votes, by out-shouting one another, by political strategy, or, if need be, by force. In no place is the irrationality of our methods of settling important social questions more obvious than in the settling of international disputes through force of arms. The human brain could not conceive of a more irrational thing than war and yet we have developed a series of pseudo-rationalizations to justify it. In the simplest terms it is but a retention of the most barbaric and elemental weapon of the crudest savage. And yet it is one of the chief methods still used by modern society in settling disputes.

In brief the exact sciences and the mechanical forces which surround us have developed so rapidly and so far beyond the social sciences that we are confronted with the very pertinent question as to whether we have not created a mechanism which may crush us. It has been said by that keen observer, Mr. Edward Slosson, that "Man is mounted upon a horse bigger than he can ride. . . . Science has endowed men with the power of supermen but his mind remains human. . . . He is like a pauper with a fortune, a laborer made a boss, a private promoted to command a regiment, a slave made master of slaves. . . . "

Despite the object lesson observable in the astonishing developments of the exact sciences "we still use," to quote Mr. Hammond, "a pop-gun method in the study of economic problems." Our methods are very unscientific, often very irrational, and as a result, poorly supported. If there is to be any solution at all it must come through more and better research in social sciences. Social sciences must receive better support; leading social scientists must be endowed. Governments, business men and philanthropists must aid, else the marvelous superstructure built up by the exact scientists may come crashing down due to the flimsy social mechanism underlying. The late war raised the question in many people's minds. Far-seeing people continually dally with the phenomenon; philosophers as well as scientists warn us and yet relatively little is done. Thus far social scientists are fighting a defensive battle; the masses as yet, and certainly the business men, care little what social scientists do or say, so long as the technicians con-

tinue to advance their material welfare as they have been doing.

It would seem that all rational persons with an enlightened self-interest must be concerned with the welfare of the scientists in the social science fields; they must aid them, endow them and encourage rational and scientific methods in the conduct of social affairs whenever and wherever possible. If rationality means anything at all this appears to be the proper means for securing sound advancement in human welfare. Such support, it is to be feared, will come slowly; the general public attitude is against it; the uncertain and intangible do not have the appeal that the more certain and the more tangible developments do. And under the most favorable conditions and with support even more liberal than that given to the exact scientists, real results must come very slowly and haltingly.

A realization of these apparent facts must convince us that those who work in social science fields are working under terrific handicaps when compared with their brothers in the exact sciences. The possibilities for genuine achievement and true distinction are almost infinitely less. Workers in these fields can only express a hope rather than a well-founded belief that they may be among those scientifically minded persons who may accomplish something of real value in this world. They are in fact little more than pop-gun or pick-axe scientists. But the fault is not their own. They are handicapped not only by the methodology they must employ but by lack of sympathetic understanding on the part of others and by lack of adequate financial support. The limits of their methodology can not be changed appreciably, but a better comprehension of the fundamental nature of their work can be cultivated and a far more liberal financial support must be given.

NOTES ON A MODEL LANGUAGE

By Dr. MAX TALMEY
NEW YORK, N. Y.

I. Qualification for the Construction of the Model Language

A LANGUAGE expressive to the greatest possible extent and free from the faults inherent in all natural languages would be beneficial to persons of different mother tongues who, by education and training, are able to communicate to one another ideas of real value. Such a language serving the need and advantage of the substantially educated people of the various nations may be designated as the Model Language (ML) to distinguish it from the International Language (IL) by which is usually understood a language common to the masses of all nations, excellence being subordinate.[1] Elsewhere[2] the writer has pointed out that an IL in this commonly accepted sense is not needed at all. The present essay is not concerned with such an IL, but deals with the ML as defined above.

The ML can only be a constructed system. The answer to the question, who is best qualified for the task of constructing it, follows from the consideration of the views of an eminent scientist regarding language in general. In "Weltsprache und Wissensch." Wilhelm

[1] In modern times Universal Language (UL) has become synonymous with IL, but originally UL meant the same as ML.

[2] "Arulo," p. 43.

Ostwald advances the following statements:

(1) Every language represents a group of signs coordinated with a group of conceptions in such a way that every particular conception has its particular sign.

(2) The system of conceptions is the only thing that matters; for with them one may coordinate arbitrary signs, and the value of the resulting language remains the same irrespective of the signs selected. The accidental character of the various systems of signs and their historical change are not worthy of painstaking study. The signs are far less important than the conceptions, and sink into insignificance by the side of them. Yet philology has occupied itself exclusively with the signs. This is a profound scientific mistake.

(3) The interpretation of language as a system of arbitrary signs coordinated with the conceptions has as yet not been fully appreciated by professional philologists. For this reason vague and mystical notions, as those of the "profound sense of language," of language as an "organic being," are very prevalent, especially among philologists.

(4) We regard language "historically," we look upon it as something miraculous, a venerable inheritance from our ancestors to be cautiously preserved and not to be attacked or transformed of our own authority. To improve a living language is considered so monstrous an idea that it has never been seriously discussed. Especially philologists oppose impassionedly such ideas, being intent upon conserving the inheritance in as unchanged a state as possible. But language is merely a technical means of the conveyance of thought, and the notion of its being supernatural, untouchable, is entirely erroneous.

The preceding statements are controvertible in some respect. But one can hardly dissent from Ostwald's view that of the two factors constituting language the conceptions are essential and the signs comparatively unimportant; yet "philology has occupied itself principally with the signs." Further, one must admit his statement that the prevailing notion of language as something miraculous, untouchable, is fostered in a great measure, if not chiefly, by professional philologists. It follows that tradition and training unfit them for being the architects of the ML.[8] For here the signs are selected "of our own authority" in conformity with logical reasoning and their "historical change" does not come into consideration. The treatment of the conceptions and the rational selection of the signs evidently appertain to the domain of logic. Hence logicians are best qualified for the construction of the ML, and systems proposed to play its rôle are to be estimated by the standards of logic. The writer, a lifelong student of the problem of the ML, finished some time ago the manuscript of a book on the scope and essence of the ML, treating all its aspects and offering suggestions for its construction. The work is entitled "Logos" and is intended to be submitted to the judgment of logicians. Its *leitmotif* is the concern for a system of "signs," or language, conforming to reason and free from the bonds of conventionality. It is this idea that the above title intimates; for "logos" means the "rational word." It must form the basic element of the ML in order to lead endeavors in its behalf to lasting success.

II. Sources of the Vocabulary of the Model Language

The ML must be so easy that an educated person can fluently read and un-

[8] This inference is not refuted by a recently published language the sole author of which is a professional philologist. It is claimed to be an improvement on the Language of the Delegation (LD) which is chiefly the work of the excellent logician Dr. L. Couturat. But it can be shown that in spite of substantial defects the LD is, on the whole, far better than the new language.

derstand any text after one short lesson or two and with the occasional help of a ML-national dictionary. Because of this requirement the words must be a posteriori, *i.e.,* taken from the natural languages, either international (itn., common to several principal languages) or national (ntn., belonging to one natural language), but not a priori, *i.e.,* newly invented. A posteriori words are far easier than a priori ones. The itn. words are easier than the ntn. ones, hence the former exclude the latter. Only when an itn. word does not exist for a certain conception, is this one to be rendered by a ntn. word. The number of itn. words is far too small for an efficient language, and lack of words for conceptions expressible with one word in the natural languages causes difficulties. Hence recourse must be taken to ntn. words.

The most important reason for excluding a priori words is that they would open the door to the whims of language inventors. But if the ML is restricted to a posteriori words, its whole vocabulary is independent of the fancy of authors. The itn. words are evidently given, but it is not so readily apparent that also the ntn. ones are determined, can not be selected by an author from any language that pleases him best. Certain words can only be taken from a certain language, as a few illustrations will elucidate. We are looking for expressions of the following conceptions or definitions:

(1) A matter of taste or a pursuit engaging unduly the attention and interest.

(2) Detriment suffered by undertaking something without the necessary experience.

(3) Damage done dishonestly by a laborer to the work entrusted to him.

The only words available for these definitions are: (1) *fad,* English; (2) *Lehrgeld,* German; (3) *sabotage,* French. It follows that the three needed expressions are determined, can not be any other ones but fad, Lehrgeld, sabotage. Yet these words are national. Previous publications of the writer furnish numerous other illustrations.

Sometimes one of several languages possesses for a certain conception a word which is the best because it is fairly univocal in that language while the words of the other languages are too ambiguous in these, or because it is the shortest or most euphonious one. For instance, we want a word for this definition: to draw a line through a passage in order to invalidate it. The English expression *to strike out* is too long; the German word *ausstreichen* is ambiguous in German and non-euphonious; but the French word *raturer* is precise in French and well-sounding. Hence the French word has to be selected.

Sometimes a word has to be taken from one language rather than from another one because the word of the latter conflicts with a word selected before. Even an itn. word has to give room to a ntn. word to avoid such a conflict.

The case that for a certain definition each one of several languages offers a word adequate in every respect is extremely rare. Unity of the ML will not be appreciably affected by leaving here the selection of the needed word to the taste of authors.

The ntn. words, too, are therefore determined, like the itn. ones. The objection that a language composed of words of various sources would be a *mixtum compositum* unfit for use is refuted by the most powerful and most expressive language, English, which contains Germanic, Latin, Greek, French and other root words.

Latin offers a rich source of words, which, as a rule, are also itn. But not all Latin words are itn. Systems using exclusively Latin words, such as Latino sine flexione, and other devices, are

fraught with difficulties. Because of the requirement of facility the words must be as itn. as possible. The degree of internationality of a word is measured with sufficient accuracy by the number of languages having that word in common. Another measure is proposed, namely the number of people in the whole world understanding that word. This number is unascertainable; the figures computed are fanciful.

When there are no itn. words, recourse is to be taken, in the first place, to the languages of the great nations, in the second place, to Latin and Greek, and, in the third place, to the languages of the small nations. The number of educated people acquainted more or less with Latin and Greek is larger than the number of nationals of a small nation.[4]

III. Extent of the Vocabulary of the Model Language

How many words are needed in the ML? The following considerations furnish the answer to this question. The main factors making for difficulty of the natural languages are unequal, or lack of, expressiveness and excessive multivocalness of the words. Very often one language has a word for a conception, and another language can express it only with a troublesome periphrasis. Consider, *e.g.*, the following conceptions.

A. 1. To look at a thing briefly, hurriedly; 2. To deter by a bold or confident manner; 3. To entrust a thing to the post office for delivery.

B. 1. To make one feel as if he were at his own home; 2. To declare a person incapable of managing his affairs; 3. Rejoicing at the misfortune of others.

C. 1. Self-confidence in dealing with others; 2. One who unlawfully takes the place of a wife; 3. Trickery having the show of honesty.

The definitions of A can be expressed with one word only in English: *to glance, to bluff, to mail;* those of B only in German: *anheimeln, entmündigen, schadenfroh;* those of C only in French: *aplomb, maîtresse, chicane.* An Englishman is at a loss how to express six of the nine conceptions. The same holds true of a German and Frenchman.

R. C. Trench[5] cites "words, which one people possess, but to which others have nothing to correspond so that they have no choice but to borrow these, or else to go without altogether." Many such words are treated in "Lexikologio," etc.[6]

A language possessing a word for a conception inexpressible with one word in another one is essentially richer in this particular instance. General essential richness of a language is represented by the number of conceptions expressible with one word. English is probably the essentially richest language. Synonyms do not make a language essentially rich, but merely more pleasing through variety of expression. They never cause misunderstanding, hence they need not be excluded. Synonymity in moderate degree is recommendable; it helps to obviate tedious repetition. But it should not be exaggerated since it is non-essential for expressing conceptions. Multivocalness, however, often due to essential poverty, must be avoided; it engenders difficulty.

Essential richness does away with the two main factors of difficulty of the languages. An extensive vocabulary does not necessarily tax the memory too much. No English student needs to remember all the words contained in the Standard Dictionary. It is a great fallacy that a language is so much easier, the fewer root words it possesses. Just the opposite is true. When the language of a writer has no equivalent for a word of another language, he has to apply the means of derivation, com-

[4] See "Logical Shape of the AIL," p. 3.

[5] "Study of Words," p. 119–121.

[6] Filologiala Temi; Raporto 28; Supplemento.

position, or periphrasis to express the corresponding conception. This is often an arduous task. A literary person needs a rich treasure of words laid down in dictionaries. If only a writer can find there the required words, his task is much easier than when he has to forge them. The ML must be adequate to translate all principal languages. It will remain inadequate so long as it lacks equivalents for their words. It is impossible to enhance the richness of a natural language, but there is no limit to the enrichment of a constructed language.

The answer to our question is now apparent. Besides a fair amount of synonyms so many words are needed in the ML that one is available for every conception expressible with a single word in any principal language. The ML would thus become the essentially richest language and thereby the easiest one. This aim may remain an unattainable ideal. Many ntn. words being unfit for the ML, sufficient a posteriori words are unobtainable. But for a great many conceptions adequate words can certainly be procured. They would bring us always nearer that aim. The natural languages, foremost among them English, show the way of approaching it more and more. English had no words for the conceptions "assurance resulting from self-confidence," "establishment for the diversion and instruction of little children," etc., and supplied these wants by appropriating the French and German words *aplomb* and *Kindergarten*. The ML can apply this procedure generally and systematically; it can adopt any suitable ntn. word. The task of enriching the word treasure in this manner requires many years' labor of many cooperating linguists who are competent, liberal-minded and familiar with the comparative expressiveness of the natural languages.

IV. Comparative Efficiency of the Languages, and Translation

Foreign words, such as *Weltschmerz, Zeitgeist,* are used in English for want of equivalents of equal impressiveness. To express clearly the idea of the first word in French one needs a lengthy phrase: *sentiment mélancolique causé par les déceptions de la réalité.* Such observations engender the surmise that some languages are more efficient than others. This can not be proved directly. There are, however, two criteria for estimating the comparative general efficiency of the languages.

One is the adaptedness of a language for the study of other languages. Intelligence, zeal, opportunity, etc., being equal, foreign languages are acquired better by some nationals than by members of another nation. This fact has but one explanation: the mother tongue of the former is a better means for studying languages than that of the latter. The instrument for learning a foreign language is one's mother tongue, and with a finer instrument better work is accomplished. This criterion can not be verified experimentally by reason of the above factors. Zeal, opportunity, etc., are unascertainable; intelligence, unmeasurable. The intelligence tests so fashionable in our day may be sufficient to establish imbecility, but are worthless for comparing normal intelligences, and even more so for contrasting intellects surpassing the average.

The second criterion is fitness for translation. The more faithfully one can translate with a certain language, the more efficient it is. The faithfulness of a translation is determined by the approximation of the retranslation to the original. This criterion is verifiable by an experiment. Before describing it we must show the requirements of good translation.

A good translation must, in the first

place, convey fully and exclusively the ideas of the original and, in the second place, preserve its linguistic characteristics and beauties. The second requirement can only be fulfilled by translating literally, by imitating, as far as possible, even the idioms. These may be divided into (1) pure idioms and (2) slightly idiomatic phrases. Literal translation is inapplicable to the former. They have to be rendered in some logical manner or through exactly corresponding idioms of the translating language. The latter mode of translating pure idioms is the better, more genial one. Far more frequent than these are the slightly idiomatic phrases, and they are well intelligible in literal translation. Rendering them logically deprives the translation of the beauties of the original. The languages obtain their charms by their peculiarities, by their slight deviations from strict logic. Too much of it is annoying. Faithful imitation of the original is therefore to be applied when it causes no misunderstanding. The limit to which one may go is set by the intelligibility of the translation and by the norms of fairly good style of the translating language. Literal translation offers a double advantage: it is far easier than the logical one and reveals to the student far better than the latter the true character of the language translated.

The preceding considerations lead to the following principle of translation: *In translating model prose one must follow the original most faithfully, word for word, going even as far as to observe the same order of the words, provided only that the translation is well intelligible and the norms of fairly good style of the translating language are not infringed.*[7]

Compliance with this principle is particularly important regarding the ML. For one of its objects is to reveal the character of a language to all educated people speaking different mother tongues. Pure idioms must be rendered in some logical manner since the ML possesses no corresponding idioms. In all other respects literal translation is to be applied. Its advantages mentioned before are here even more pronounced.[8]

Our experiment can now be appreciated properly. An author competent in languages A, B and C translates an original of A into B and C in conformity with our principle. The two translations are retranslated into A, the B-translation by a second author and the C-translation by a third one, both unacquainted with the original. Language B is more efficient than language C if the translation from B deviates from the original less than the retranslation from C does. The experiment is less reliable when both retranslations are made by one and the same author.[9]

In greater adaptedness for translation may lie one of the reasons why some natural languages possess a literature of translation surpassing quantitatively and qualitatively the literature of translation of other languages.

[7] Exhaustive Text Book, p. 17.
[8] Lektolibro, p. 22.
[9] Supplemento, p. 1.

TO-MORROW'S GASOLINE?

By Professor R. B. SMITH
COLGATE UNIVERSITY

THIS question of the duration of the oil supply has been discussed so often that another article may seem unnecessary, but if a few more people are set to thinking by this attempt, the time and effort necessary will be well repaid. Each of us looks at the problem from a slightly different angle and so something may be contributed to our general knowledge of the subject.

It is useless to say that the petroleum supply will fail in five, ten or any other definite number of years because such predictions have been made again and again and the coming in of a single gusher in a new field will entirely upset all calculations; but one thing is as certain as anything in the physical world can be and that is, we have to-day less oil than we once had and to-morrow we are going to have still less, because we can not "eat our cake and have it too," no matter what the average person thinks. Some day the domestic oil barrel will be empty—and then what?

It is unthinkable that we must some time, perhaps within the lifetime of even some of the older of us, throw all our automobiles, airplanes and other gas-driven necessities onto the scrap heap. We can not believe that a civilization so largely founded on the internal combustion engine will be wrecked for want of materials to drive that engine. But what are the probable future sources of such materials and what is the probability that they will be developed in sufficient quantities to meet our needs as gasoline fails?

Men engaged in the business of refining oils and producing from the fields do not seem to be worried about a future supply. One man of prominence said a few years ago, "Fear of exhaustion of the world's supply of petroleum is a bug-a-boo. There is plenty of petroleum and will be for a long time, but the question is, is the United States willing to pay the price for an adequate share of the world's supply?" A chemist of one of the world's greatest refining companies remarked that his company had oil enough in sight to take care of their refineries for many years to come, and yet the Geological Survey told us in 1920 that we had petroleum in the United States to last about twenty years more, that is to say that by 1940 our native supply would be practically all used. Such predictions have been changed from time to time, the limit has been extended, but already we are importing heavily from Mexico and it is believed by many, who should know what they are talking about, that we have already passed the peak of our production and are on the down grade. The pessimistic predictions of the Geological Survey were partly based on the assumption that no wells would be productive if drilled deeper than 2,700 feet, but to-day in the California field we have wells giving large yields from depths of over 5,000 feet. Yet no matter how many more fields we discover, how deep we drill our wells, there must be a limit somewhere; and yet there seems to be no limit to the number of automobiles we can build and sell. The curve of production of gasoline from native sources is sure to fall, while that of motor cars is rising.

Efforts to find oil in our island possessions have not been a success and after

a five-year effort one great company has withdrawn its explorers and given it up as a bad job. There is plenty of oil in Canada according to the incomplete surveys that have been already made, but much of it is almost within the Arctic Circle and the difficulties of getting it out of the ground, refined and to the market are so considerable that we can not depend on the Canadian supply for some time to come, if ever. There is plenty of oil in the world, but it is not within the boundaries of the United States, and since we have here so many more automobiles than all of the rest of the world, the outlook for us is not so good. Russia has probably more oil than we have and the same may be said of other countries, but if oil must be brought across the Atlantic or Pacific to our refineries the outlook for gasoline at anything like present prices is none too hopeful. Some day we may be paying fifty cents or more for gas and then many relatively poor people must lay up their little cars, unless of course we scientists can do something about it.

The general public has an almost childlike faith in the chemist and engineer and believe that we can take rabbits out of hats and pick diamond rings and first-class watches out of the air, but it takes time to set up the magician's table, and also it costs a lot of money. To fill the almost empty oil barrel is our task and it will be accomplished, but the difficulties are much greater than people think and much hard work must be done and much money spent before our task is finished. Furthermore, our present oil barrel has a number of leaks in it, so it would seem that the most logical thing to do at present is to stop up the holes, making what we have last as long as possible and give the scientists a fair chance to make good on the public expectation. Let us see what some of these leaks are and what can be done about them.

It has been estimated by various students of the problem that a very large percentage of the oil of any field is left in the ground. Wells are not completely emptied; they become flooded with water and other causes rob us of much of the oil we might expect. Some put the amount left in the ground as high as 80 per cent. of the total in the field. Now how are we going to get that 80 per cent. or some good portion of it? Some have tried flooding to raise the oil, but this eventually spoils the wells. Compressed air has been tried, solutions of soda ash have been poured down old wells in the hope that the oil in others might be increased in flow. Many other tricks have been tried but thus far with comparatively little success. We may hit upon some scheme to make our fields yield better, but as yet the prospect is not very promising.

There are other things we can do, however, every one of us. For example, we may conserve oil on the car; we can make a gallon give us more miles and can stop waste in other ways. It has been calculated that there is enough latent energy in a gallon of good gasoline to run a Ford car 480 miles on a level hard-surfaced road on a day when there is no wind. The writer does not know who made this calculation or how near the truth it is, but granting for the sake of argument that it is true, this means that we are getting an efficiency from our gallon of gas of but 4 per cent., as our average is somewhere near twenty miles. The steam engineer and the electrical engineer, the chemical manufacturer, etc., would feel that a 4 per cent. yield on any process was pretty small, and while we may never expect to get 100 per cent. of the energy from a gallon of gasoline in terms of useful work it is safe to say that our automotive engineers will not long be satisfied with our present efficiency, especially in view

of a failing petroleum supply and rising prices.

We are wasting large quantities of petroleum in our city gas plants. Gas in earlier times was made by the distillation of bituminous coal of high volatile content, and such gas had high lighting powers. Then the cheaper and more efficient water gas process was discovered whereby steam is passed over incandescent carbonaceous matter and a gas results which is composed chiefly of carbon monoxide and hydrogen, both of which burn with a non-luminous flame. The law demanded, and I believe still does, that city gas should have a definite illuminating power, and to achieve this the makers of water gas had to mix with their product a certain amount of oil gas made by the destructive distillation of petroleum. Since to-day we use gas almost entirely for heating or industrial purposes and almost never for lighting, the illuminating value of a gas is of little concern to us and this ancient legislation should have been repealed long ago and the petroleum used in the gas industry released for other and useful purposes.

Higher compression engines will enable us to use the higher boiling constituents of petroleum. Some of us complain that we now have too much kerosene in our gasoline, but the engines of improved design should be able to take care of kerosene all right. The knocking of the engines with these higher boiling substances has been one reason why they have not been more used in the past, but antiknock preparations seem to be doing away with this difficulty. There has been some hesitation in using such antiknock preparations as tetraethyl lead, used in "ethylgas," because of the serious danger of poisoning, but since the danger is recognized and precautions taken against it there seems to be no reason why it should not be used, and thus much material is thrown into the market for our use which was of little value a few years ago.

The writer does not believe that the most efficient type of carbureter is on the market; improvement can still be made. We may expect that the designers of the future will give us cars, the mileage of which per gallon of gas will exceed the sweetest dreams of present-day motorists. Indeed, a statement was made several years ago in one of the scientific journals that there was then a carbureter possible which if installed on the old-fashioned Ford cars would have saved enough in a year on the gasoline bill to allow the purchase of 75,000 more Fords. If this is true Mr. Ford and Mr. Rockefeller should get together and talk things over.

Another direction in which we may save gas is in the use of smaller and lighter cars. There is much progress being made in this direction and yet other countries seem to be doing better than we are because of the greater cost of gas, and some of the mileages they have achieved on a gallon of gas have been remarkable. During the war, when it was necessary to save for the needs of our overseas forces, it was not considered good form to leave an engine idling, and yet we seem to have forgotten our lessons learned at that time to such an extent that much gas is being wasted in that way. The writer always has a feeling of disgust at seeing a car standing still with the motor running while the owner is passing the news of the day in some store or office. If the car owner could realize that by wasting gasoline he might be depriving himself or more certainly his children of the pleasures and convenience of cheap gasoline he would not be so careless.

Running our trains and ships with crude petroleum may be convenient and cleanly, but it is wasteful, as we have other means of propulsion that are

about as good. The development of the steam turbine for the sea, the increase of the use of electricity for the shop and for land traction would seem to make it entirely unnecessary to use petroleum either for traction or in the factory. It would seem far better to save this for our cars and trucks. Heating our houses constitutes another waste of petroleum, and it is safe to predict that those who are now enjoying the freedom from work which this method of house heating makes possible will soon again be shoveling coal and carrying out ashes as of old. Perhaps we may be driven in our cities and small towns to some form of central heating which will do away with household furnaces entirely. Why not? If we can pipe water and gas into our houses, take away the sewage through pipes and bring in electricity over wires, is it too much to think that we will some day have sense enough to pipe heat into our homes and places of business from some central plant? Then this waste of petroleum will be eliminated and our oil still remaining will be conserved a much longer time.

But granting that the oil is being exhausted and that the end will come some time, what seems to be the most likely substitute? It is, of course, impossible to go into much detail concerning the several substitutes that are possible, but they may at least be indicated, and of these alcohol is the first.

Alcohol in place of gasoline has many advocates. Possibly they feel that filling the gas tank as well as the driver with the "joyous juice" may add new glamour to motoring. The rest of us have our doubts. But it is quite probable that alcohol will play a large part in replenishing our supply of motor fuel, and yet there are some properties of the substance that make it much less desirable than gasoline. In the first place is the fact that an engine starts badly on alcohol. This difficulty may be overcome by the use of ether for starting because if cheap alcohol is available we will also have cheap ether. Furthermore there is not the same energy in a gallon of alcohol as in a gallon of gasoline, so we will have to stop at the filling stations more often. It is also a question whether alcohol can be produced in large enough quantities, although it can be made from almost any organic material. Almost any vegetable matter can be changed into sugar and when this is treated with yeast nature will take its course, a fact well known to the home brewer and distiller. As one old lady once remarked when she was listening to a lecture on the wonders of chemistry, "What is the use of trying to make people temperate when a man with a buck saw can get drunk on a piece of fence rail?" So easy is it to convert vegetable matter into alcohol, even such material as cellulose, that a single copy of the Sunday edition of your favorite paper might be converted into enough to cause the partaker thereof to become most optimistic, for a time at least. If we were to use food crops for alcohol, the amount of land that we would have to employ might be more than we could spare and still feed our people. All sorts of waste material from our sawmills, straw, grass, cornstalks, cotton plant wastes, pea vines, and a thousand other things can be used which now have no value, but the question is one of cost; and even if all such waste should be utilized there would not be enough alcohol to take care of all our need for motors. The Germans have developed a special kind of potato for alcohol manufacture, a potato full of starch, large but flavorless and unfit for food, but here again the question of sufficient land enters in. Perhaps some sort of tropical vegetation might be used and the center of alcohol production may be the dense jungles near the equator where vegetation grows so rapidly that no form of human life can thrive

in such regions until it is cleared. Oh, yes, we chemists can make you motorists a lot of alcohol. But we predict you won't like it as well as gasoline and you won't like the price either until very large scale production is reached.

Shale oil, distilled from the great mountains of shale in some of our western states, offers some most interesting possibilities for a future source of petroleum products. We need lubricating oils as well as motor fuel, and these shales will furnish them while alcohol does not. Petroleum has been made for a long time from shale, especially in Scotland where so little of anything goes to waste. The Scottish shales lie fairly deep in the earth, are in thin beds, much folded and irregular so that mining is difficult. But it seems that if the Scotch can make a success of the industry under their working conditions we can utilize our shales which are in mountain-like masses in Colorado, Utah, and other places. Instead of mining and hoisting the rock to the surface we have in many places only to blast it out from the hills and drop it by gravity to refining plants along the railroads.

It has been known for a long time that oil shales contain combustible material, the fact having been discovered by two enterprising miners of pioneer days. These gentlemen built themselves a nice log cabin with a fine fireplace and chimney. Fireplace and chimney were laid up with some flat black stones they found in the neighborhood; when they built their first fire, fireplace, chimney and cabin went up in flames, a discovery of the properties of oil shale which we might compare to the Chinese discovery of the delights of roast pig—convincing but expensive.

It is calculated that the oil shales of Colorado alone will yield twenty billion barrels of crude oil much like petroleum, equivalent to about one billion barrels of gasoline, and Utah can furnish as much more. There are other promising sections also. Another survey brings us the information that there is ten times as much oil in the shales of Colorado as has been produced in the United States since 1859, the year of first production. This is certainly good news to a nation clamoring for more oil, but we must not forget that it is a long way from the oil in the mountain to the gasoline tank on our car. In the first place we must have a whole army of miners, perhaps I should say quarrymen, as it is more of a quarrying than a mining proposition, to get the shale out, and it is estimated that as many men will be required as are now employed in the present coal industry. The development of shale oil would almost at once take up the slack in the coal-mining industry, which seems to be suffering from the fact that we have more miners and mines than we can profitably use. Then we have the difficulty of distilling the oil from the shale, and this will demand a manufacturing organization much like the present for refining petroleum. Probably the refining facilities of to-day will be applied to a very large extent. Certain by-products of shale would be very profitable, such as ammonium sulfate, flotation oils, etc., and the value of these would greatly reduce the cost of manufacture of our gasoline and lubricants. But it is evident that under the most favorable circumstances it will be a long time and a vast amount of money must be spent before the shales can furnish as much gasoline as we are now using each year. Shale, however, seems to offer a source of gasoline which will be very dependable once it is developed, and we do not need to fear that the supply will fail for a long time; many of us believe that here is our most probable source of oil in the future.

The distillation of coal tar and the by-products coking process offer a considerable quantity of what is called distillate,

a liquid consisting largely of benzol and toluol, and this has already been used with considerable success in internal combustion engines, either alone or mixed with gasoline. Indeed many of our filling stations are selling blended gasoline of which distillate is a considerable constituent. There seems to be some difference of opinion as to the value of distillate in an engine: some say that there is more carbon formed, spark plugs become fouled more quickly than with straight gasoline; yet others say they have used the substance for years with no more trouble than from gasoline. But if all the coal produced in our year of highest production had been coked by the by-product method and all the tar distilled for its maximum yield of distillate, only about 70,000,000 barrels could have been made, or enough to take care of our motor needs for the year 1917. But to-day we have certainly a third more cars than at that date and so it is evident that under the most promising conditions distillate will not meet our demands. It will probably be very useful as far as it goes and will greatly help to fill an oil barrel which contains alcohol, shale oil and other things equally interesting. It should be added that at present the total production of distillate meets about 2 per cent. of our gasoline demand.

We have believed for years that if we could make coal combine with hydrogen and if we could get cheap hydrogen we could synthesize hydrocarbons like those found in petroleum. At last in the Bergius method such a process has been worked out and is being operated profitably in Germany. There, of course, it does not have to compete with gasoline as cheap as we have it here in the United States. Cheap hydrogen we can obtain from the water gas process. In most common fuels, with the exception of anthracite coal and coke, the ratio of carbon to hydrogen is about 16 to 1, while in the hydrocarbons which make up petroleum the ratio is about as 8 to 1. Now the question arises, if we could increase this ratio in coal could we not obtain the hydrocarbons? Bergius undertook the solution of the problem and has made a success of it. In his process the coal is broken up into small grains about the size of wheat grains, then is mixed with a little crude oil or tar and a catalyst, in a strong cylinder, and over it is passed water gas under a pressure of 3,000 pounds to the square inch and at a temperature of about 800° C. The result is a liquid that is much like crude petroleum except that it lacks some of petroleum's low boiling constituents. The exact nature of the catalyst is not known, although it is probably one of two types, either a mixture of copper, manganese and cobalt compounds or copper, cobalt and uranium as oxides, as the finely divided metals or both. In a recent experiment carried out at the Coal Conference of 1928 in Pittsburgh, 104 gallons of crude oil were obtained from a ton of coal. From this, forty-five gallons of good gasoline were obtained by distillation; also fifty-five gallons of oil and four gallons of tar. The oil in turn yielded twenty gallons of spindle oil, thirty gallons of high-grade motor oil and five gallons of cylinder oil and grease. The gasoline did not knock when used, probably due to the presence in it of considerable quantities of unsaturated compounds, more than in gasoline made by straight distillation of petroleum.

The importance of this Bergius process may be assumed from the rumor that the patents for the United States have been purchased by one of our great refining companies. It will, without doubt, be placed in operation as soon as the price of natural gasoline reaches a high enough point to make the new process pay. One writer has said that the "Bergius process is like a large endow-

ment policy for the future of the motor industry." It is a nice thing to think about and it is quite probable that much of our gasoline of the future will be made by this process. Possibly it will be the universal process, but the writer feels that all of the various possibilities for making gasoline substitutes will be exploited and we will fill the empty gas barrel with many different types of materials, all of which will serve to help carry the burden.

Some research has been carried out on methods of making gasoline synthetically from acetylene. This is probably only a laboratory curiosity at present as the cost would be prohibitive. Also some success has been attained by Fischer, in Germany, on a process of combining carbon monoxide with hydrogen by passing them at low pressure over suitable catalysts of iron or nickel. This has already resulted in the commercial production of methyl alcohol and other useful products as well as a series of hydrocarbons. There is already a product of this process called synthol, used as a gasoline substitute, and we are waiting for further developments with great interest. Some believe that these reactions have only theoretical value and that they can not be worked out on a commercial scale, but one great argument in favor of such a process as this of Fischer is that it can be carried on by the common city gas plant. The manufacture of gas is a more or less seasonable operation as much more gas is consumed in winter, hence expensive equipment has to remain partly idle in the summer. Now if such plants could be utilized for making gasoline in the summer, full-time use of the plant would be possible, and any organization is most economical when being operated at capacity. Equalization of the load on the gas plant would be a good thing all around.

One of the officials of the Bureau of Mines expressed the feeling that synthetic gasoline will surely be on the market as soon as it is needed and that the industry will be so developed that it will ultimately meet the full demand for motor fuel. The man in the street will probably never realize that the fuel he is purchasing never came out of the ground, so gradual will be the change from one kind to the other. No one substance, no one process will meet the fuel situation completely, but at first all will be working together, until one process shows its superiority over the others and the weaker drop out of the race.

Every human need thus far has been met in some way or another, and the replenishing of the gasoline supply will be no exception. We feel confidence that this need will be met and met fully. Scientific and engineering progress has been so amazing in the past fifty years and the rate is to-day being so accelerated by research that we can never doubt the future. But research costs money and takes time; it demands the hardest thinking. And to solve this great problem of the gasoline supply tomorrow we must have the most cordial cooperation between chemists and engineers, and the men of money must be prepared and willing to furnish an almost incredible number of millions which will be eventually returned to them with many other millions added.

VITAMINS AND THE WORLD OF PLANTS

By Dr. NORMAN ASHWELL CLARK

THE DEPARTMENT OF CHEMISTRY, IOWA STATE COLLEGE

For nearly seventeen years it has been known that animals, including the human race, require in their diet minute quantities of organic substances of unknown composition—termed vitamins—before growth can occur or health be maintained. By an ever-increasing number of searchers these essential substances have been investigated, in order to find where they exist, to learn their effect on the body and to isolate them in a pure state. The influences, however, which lead to the production of these vitamins have been much less thoroughly studied than the effects they cause; nevertheless, knowledge is gradually accumulating which may prove of importance in food production.

While success in the isolation of these substances has been small and we can not yet point to any group of chemicals and say "These are the vitamins," the major effects on the animal body of their absence in the diet are fairly well known. The particular functions which are stimulated into action by their presence—whether one vitamin acts on the nucleus of all the cells or another on some special organ of the body—are not yet perfectly understood but the information that has been gained has played no small part in that "newer knowledge of nutrition" which is becoming so widely diffused.

Because the composition of the vitamins is not known, they are named by the letters of the alphabet. The first is A and its function is "growth-promoting." A constant supply is essential for growth in young animals, although it may be stored to some extent in the adult body. Absence produces also the disease of the eyes known as xerophthalmia. A is found in green leaves, in yellow fats and in liver oils, especially in cod-liver oil; vegetable oils, as a rule, lack it. B is called the water-soluble vitamin, and is now known to consist of two, very closely associated in nature—the anti-neuritic, which is tested by its power to cure paralysis, particularly in pigeons, brought on by a diet such as polished rice; and the growth-promoting B, which may also prevent pellagra. These are present in green leaves and in seeds; yeast contains large quantities. C is the anti-scorbutic vitamin which prevents scurvy. It is not found in seeds but is plentiful in young sprouts. Citrous fruits, tomatoes and green leaves contain it. D is the anti-rachitic, associated frequently with A. This vitamin prevents rickets in children and has a great deal to do with good bone growth. One of the chief sources is cod-liver oil, but ultra-violet rays, either from sunshine or produced artificially, may take its place. A little-known chemical substance, ergosterol, when irradiated with ultra-violet light, has the same effect in the diet as the vitamin. The last is E, without which reproduction in animals ceases. E occurs in oil extracted from the germ of the wheat seed and in some green plants; it has only recently been investigated and reported.

From the observation that the sources of the vitamins are found so frequently in plants, it seemed possible that the animal world might be dependent upon the plant world for its supply. Investigation has shown that "the vitamins present in animal tissue, and in products of animal activity have not originated there, but have been transferred from a vegetable source." The cod does not produce the vitamins which are obtained from its liver. The cod feeds on smaller

fish, such as the herring, and these in turn eat the planktons—floating worms and larvae—whose food consists of microscopic marine organisms, among which are unicellular algae called diatoms. It is the diatom which produces the vitamin, and this is passed through the various stages unchanged until it is concentrated in the cod-liver oil.

Thus the vitamins are formed outside the animal world, but are found in plants and in certain micro-organisms. Questions as to their production at once suggest themselves. How does the plant obtain the vitamins? Does it manufacture them or get them ready-made from micro-organisms? What conditions are best for their production, and is it possible to increase the vitamin content in the plants used for food? Does the plant or the micro-organism need these vitamins, or other similar substances, in order to live? These aspects of the subject have received comparatively little attention, but are not altogether unknown.

It may be asked why it is necessary to investigate these questions, if the ordinary diet of the human race supplies a sufficient quantity of the vitamins for good growth and health maintenance. Quite apart from the unsuspected facts of value which may be discovered—a condition which so frequently occurs when such investigations are made—it is becoming more and more evident that certain types of diet, not only among the rice eaters of the East or the millet eaters of India, but also in this country, show a deficiency in the vitamin content—a lack not sufficient to stop growth or to produce xerophthalmia or scurvy, but large enough to cause susceptibility to some of those minor ailments which so greatly cut down the efficiency of the individual, and which so quickly take the joy out of life. Attempts have been made, therefore, to trace back the sources of these vitamins and to find out conditions which are favorable for their formation.

An investigation was started along these lines to determine what it was necessary to feed the marine algae which produce the vitamin finally found in cod-liver oil. The first attempt to grow these diatoms in a solution of pure chemicals—an artificial sea-water—was a failure. Later, this was accomplished, and good growth of the diatoms in solutions free from organic matter was obtained; the diatoms produced vitamin A from solutions of pure chemicals. Similarly fresh-water algae, free from any trace of bacteria, were induced to grow in a synthetic solution without organic substances, and they also produced vitamin A. In the presence of sunlight these algae can form vitamins from purely inorganic constituents.

Certain algae will therefore grow and reproduce without any trace of organic matter, but this does not necessarily exclude the possibility of their rate of growth or their speed of reproduction being accelerated by the inclusion of organic substances in the solution in which they live. In the case of protozoa, microscopic organisms belonging to the animal world, it has been claimed by some investigators that organic matter contains an unknown factor—"substance X"—which is essential for their growth. This statement has been disputed by others, who hold that the unknown substance is not essential for the protozoa, but that it stimulates their life processes. It is necessary to distinguish carefully between those factors which are essentials—as vitamins are essentials for animals—and those which are not necessary for life, but which may increase the rate of growth, the speed of reproduction or the quantity of some substance formed within the organism.

If we keep this distinction in mind, and turn to the bacteria, we find that in general bacteria can not make use of carbon dioxide as a source of carbon, but are dependent on organic food for that element. Only a few, such as the sulfur bacteria, can do without the organic

material. It is particularly difficult, therefore, to find whether they need minute quantities of a special kind of organic matter which may act as an essential in a similar manner to vitamins, or even if traces of any substance act as a stimulant. There are many chances that the very small quantities needed are already incorporated in the organic matter on which the bacteria feed. Some attempt has been made to investigate this problem, but up to the present time progress has been slow and claims for the existence of such substances are generally regarded as unsatisfactory.

When we turn to the other side of the question and inquire if the bacteria produce the vitamins, we find considerable divergence of opinion. There are indications that bacteria not only manufacture the vitamins, but also produce various stimulating substances for the growth of plants. The theory has been put forward that it is bacteria alone which are capable of synthesizing the vitamins; that they carry them to the green plants, and that the vitamin content of the plant is as incidental as that of the cod. This theory, again, has not received general support.

A large number of different species of bacteria have been tested for vitamin B, with results which vary widely. While it has been shown that certain species of bacteria produce comparatively large amounts of B, others show no effect whatever when added to the diet of animals. The absence of this effect is caused, sometimes because the species produces so small an amount that the animal can not eat enough of the bacteria to get the quantity of the vitamin it requires, and sometimes because the micro-organism lacks the vitamin entirely. However, the synthesis of B by bacteria seems to be of rather general occurrence, although in varying amounts; there is little information concerning the formation of the other vitamins due to bacterial activity, and none at all whether a change of food or conditions would increase the vitamin production.

At the present time bacteria as food figure little in the human diet. It is true we use the products from a few bacterial transformations—vinegar is produced from alcohol by *Mycoderma aceti,* and Metchnikoff introduced the drinking of milk treated with the Bulgarian bacillus in order to change the bacterial flora in the intestines; but as food, *per se,* bacteria have been neglected. When we consider the amazing changes which have been brought about in animals by selection and feeding, and the ease with which bacteria can be produced, the possibilities of "bacterial farms" can not be dismissed altogether as a factor in the food supply of the future.

That micro-organisms may yet find a place in the diet is indicated by the daily use of yeast by thousands of people in this country. Yeast cells, although far larger in size than bacterial cells, are still microscopic in dimensions. Used for ages in the making of bread and in the fermentation of sugars, early in the study of vitamins certain yeasts were found to contain large quantities of the water-soluble B, and again the questions needed answering: Do the cells produce the vitamin or do they get it from their food? Is B needed for the growth of the yeast itself or is an organic stimulant necessary for the life and reproduction of the yeast and for the formation of the vitamin?

Before this discovery of vitamins, it had already been pointed out that it was necessary, in order to get good growth in one species of yeast, to supply organic matter along with the needed sugar and inorganic salts. The unknown substance in the organic material causing the stimulation was given the name "Bios," meaning growth. It occurred in widely different kinds of organic matter and was even present in the yeast itself, for the cells when crushed and added to the inorganic salts produced the same remarkable acceleration of reproduction.

Bios proved to be a stimulant but not

an essential for yeast life. True, the cells would multiply only very slowly when grown in a medium consisting of inorganic salts and cane-sugar, but reproduction did take place. For some time it was not known whether this multiplication was due to a trace of Bios in the sugar, even when it was carefully purified, but later, a simple sugar was manufactured from pure chemicals which the yeast used, growing without added organic matter. Bios, accordingly, did not act towards yeast in the same way as vitamins with animals: it was a stimulant for yeast, while a vitamin was an essential in the life of the animal. The proposal to include Bios as one of the vitamins was therefore dropped.

A large number of plant and animal tissues which contained vitamin B also contained the substance Bios: the suggestion was made that B and Bios were identical and that the same substance was the stimulator for yeast and the essential for animals. A method for the measurement of B, depending upon this and promising to be much more rapid than the feeding of animals, was worked out from the quantity of yeast produced by the vitamin-containing material. The method, however, proved to be unreliable, for evidence accumulated pointing to the separate existence of B and Bios. Investigations were published from many different sources to show that vitamin B and Bios were not only occasionally found separated in different substances, but also that chemical actions which would destroy the one were frequently harmless to the other.

All attempts to isolate vitamin B had failed, but Bios after long research gave up some of its secrets. In 1925 there came reports from three different laboratories to show that Bios was not a single substance; it contained at least two distinct parts—Bios I and Bios II—which could be separated from each other. Neither of these fractions could stimulate the yeast alone, but together they were as effective as before separation. Both Bios I and Bios II were shown to be different from either vitamin B or C; the chemical treatment which resulted in the separation destroyed entirely vitamin B.

The two Bios fractions were found to occur, sometimes together and sometimes apart, in a wide variety of animal and vegetable products. At the University of Toronto, tea siftings were discovered to contain large quantities of Bios I, and after repeated attempts a crystalline substance having the properties of Bios I was isolated from the tea. This proved to be an organic chemical —inosite—a substance which is known to occur frequently in plants, especially in the growing parts. The commercial product was found to have the same stimulating action on the growth of yeast, when mixed with substances containing the unknown Bios II, as the inosite isolated from the tea siftings.

There are two facts regarding the inosite which are worth noting. First, the yeast uses a definite amount of the inosite for each cell, and that amount can be recovered quantitatively from the cell at the end of its growth—a condition similar to a chemical "catalytic action" in which a substance starts or increases the speed of a reaction but is not itself used up. Secondly, although the yeast grown without Bios I manufactures it slowly, yet when mature the cell contains only about half as much as it holds when a supply has been furnished. As it has been shown that yeast grown without organic matter produces the vitamin, it is evident that the presence of Bios I is not necessary for the yeast to form B, unless the inosite is formed in the cell as a preliminary step in the building up of the vitamin. It may prove that inosite formation is such a preliminary process, for the vitamin supply of yeast grown without organic matter seems also to be about 50 per cent. of the usual vitamin content of the yeast cell.

The problems in connection with the green plants are even more difficult to solve than those of micro-organisms. Plants take longer to grow than bacteria or yeast, and they are much more highly organized. The quantity of a vitamin not only changes from plant to plant, but also varies in the different structures, leaf, stem, root, flower or seed. Although little more than an approach to the fringe of the subject has been effected and the problems indicated only, yet enough has been accomplished to bring out possibilities of influencing future agricultural practices.

Shortly after the discovery of the existence of vitamins necessary for animals, a claim was put forward for similar essential substances for green plants. These unknown substances were called "auximones"—meaning growth-promoting. Wheat grains which would grow in solutions of inorganic chemicals, responded quickly to additions of organic matter when part of the seed was removed after the wheat had started to sprout. This indicated that the seed might contain the auximone or plant vitamin. Water plants were therefore chosen which multiplied by putting out small leaves from the parent leaf. The new leaves separated from the others and in turn produced a new generation. These duckweeds, containing the characteristic chlorophyll of the green plant, failed to reproduce continuously in two well-known inorganic salt solutions, but on the addition of organic substances from farmyard manure or from the soil, growth was obtained. The results pointed to the conclusion that "all green plants require the presence of organic matter of a special kind for their maximum growth and development."

This statement was not allowed to pass unchallenged. At Iowa State College the same plants were tested in a large number of inorganic solutions, and it was found that by altering the chemicals it was possible to obtain a solution in which the duckweeds would reproduce and maintain their health and vigor without the addition of any traces of organic matter. The plants passed through hundreds of generations and no deterioration was shown. This removed the possibility that green plants needed organic substances as essentials, but left as an open question the stimulation of growth, or even the alteration of the plant content, by organic matter.

It was in 1840 that Liebig finally obtained the acceptance of the fact—discovered earlier by Senebier and de Saussure—that green plants acquired their carbon, not from organic matter in the soil, but from the carbon dioxide of the air. Thirty years afterwards, Grandeau indicated that at least part of the carbon might be taken in by the root, and later the presence of certain types of organic matter has been shown to stimulate strongly the growth of green plants. The effect upon the composition of the plant is not well known, and whether or not the vitamin content is affected has hardly been investigated; yet from the point of view of fertilizers in agricultural practice it is of primary importance to determine the effect upon the quality of the product. Agricultural improvement has in most instances given attention to improvement in quantity—in only a few cases where public demand has to be satisfied, or where private industry has set a standard, as in the sugar percentage of beets, has an increase in the quality of the product been the aim of agricultural practice. That this point of view may require changing in the future is quite possible, for there is some evidence that at least the vitamin content of the plant may be affected by the organic matter in the soil.

In India the observation was made that rice from different localities varied in nutritive value. The variation was traced to the soil in which the rice was

grown, and an investigation was started on the influence of soil upon the common grains of that country, of which one is millet. In Madras, millet is the principal cereal of millions of people, and in a restricted diet the vitamin value of the millet would be of considerable importance. This grain was therefore grown in three different ways: (1) on a soil which had received for years quantities of cattle manure; (2) on the same soil receiving instead of the farmyard manure, nitrogen and phosphorus and potassium as mineral fertilizers; (3) on the same soil without any additions. The seeds from the three plots showed no marked differences in size or chemical analysis, but when they were planted in a soil not especially rich in organic matter, the seeds from the plot which had received the farmyard manure produced much greater crops than the other two plots. Further, there was a large difference in feeding value—the vitamin B content of the seeds from the manured crop was greater than from the others. Wheat, treated in the same way, showed the influence of the organic matter on the next crop, and the vitamin A content was larger. It seems that in the organic matter of the farmyard manure there are substances which not only give the plant power to manufacture vitamins A and B, but also produce a stimulant in the seed which will influence the succeeding crop.

Experiments in this country failed to show consistent variation in the vitamin B content of wheat, when the soil was treated with different mineral fertilizers. Results were obtained over a series of years but with only slight indication that phosphorus fertilizers might be more favorable to the vitamin formation than potassium or nitrogen. The vitamin content of all the wheats in the series of experiments was low, but no trials with the addition of organic matter were reported. Climate, however, appeared to influence the quality of the vitamin formed. This, along with the differences in soils, may explain the large variation in the amounts of wheat required by different investigators for an adequate quantity of B in the diet. Whether the deficiency of the vitamin due to climatic and soil conditions will prove to be serious and whether it can be overcome by agricultural practice remains as a problem yet to be solved.

Although the importance of these vitamins in the diet of the human race is no longer disputed, attempts to increase the supply have been comparatively few in number. We have seen that these essential substances are not produced by animals, but are obtained by them from green plants or from micro-organisms, and that the problem of production has been scarcely touched. Certain types of marine algae contain large quantities of vitamin A, and this is concentrated in the fish which eat them. These diatoms can synthesize the vitamin from inorganic sources under the influence of sunlight, and fresh-water algae act in the same way. Many species of bacteria as well as yeasts can manufacture vitamin B. Green plants produce all the known vitamins, but in different plants and in varying quantities.

The problem is complicated by the existence of stimulating substances in organic matter which may affect the quantity of the essential vitamins formed. This is almost certainly the case with yeast, where the addition of Bios adds materially to the content of vitamin B. There are some indications, also, that on certain soils the cereals produced may vary considerably in vitamin content of A and B due to the presence or absence of organic matter. With the growing reliance upon mineral fertilizers, due to the lack of farmyard manures, the question may eventually become as important in the agriculture of this country as it is now in some other parts of the world.

PARASITISM AS A BIOLOGICAL PHENOMENON

By Professor HORACE W. STUNKARD

DEPARTMENT OF BIOLOGY, NEW YORK UNIVERSITY

THE study of parasites and parasitism has in recent years developed into one of the important fields of scientific investigation. Increased knowledge has shown that parasites play a tremendous rôle in the production of disease. One has only to note the prevalence and morbidity of hookworm, malaria, yellow fever, sleeping sickness, typhus fever, amebic dysentery, to mention only a few of the more commonly known parasitic diseases, to realize that the great scourges which have decimated populations are of parasitic origin. It is largely the prevalence of parasitic diseases that has prevented the exploitation of the tropics, the richest and most productive agricultural areas of the world. The pathogenic bacteria are parasites in the strict sense of the word, and consequently most of the illness and death among men and animals is due to the activities of these organisms.

Not only are human beings and other animals subject to attack, but statistics record that one tenth of all crop products in the world are annually destroyed by parasites. Universities, government departments, endowed foundations, scientific societies and other agencies are maintaining staffs of workers engaged in study of the medical, veterinary and agricultural aspects of parasitic infestations. Many of these investigators are directing their attention to the protozoan forms, others to the several groups of parasitic worms, while a study of the insect parasites constitutes a special section of the field of entomology. As a result of these studies there has grown up so massive an accumulation of literature that in addition to the American *Journal of Parasitology* there are several English, French and German periodicals devoted entirely or primarily to the publication of results in this field.

It is, then, generally recognized that parasitism exists in nature and that it is wide spread. Few, however, clearly apprehend that it comprises one of the most distinctive categories of animal existence, and constitutes a discrete and characteristic biological phenomenon. Careful and critical study of large numbers of parasites, belonging to various classes of animals, has demonstrated that parasitism has certain basic and fundamental characteristics, no matter in what group of animals the parasitic habit may have been developed. The same general tendencies are manifest, similar attributes and relationships appear, and similar consequences inevitably follow the adoption of the parasitic habit.

The consideration of parasitism as a biological phenomenon, and investigation of its fundamental nature, origin and interrelations, may yield results of far-reaching consequence. Experience has shown that not infrequently researches into the purely scientific and theoretical aspects of natural phenomena have led to broader and clearer conceptions and have proved more valuable than the narrowly conceived and immediately practical application of existing knowledge. It is this concept that is here reviewed: *i.e.*, the biological aspects of parasitism, the extent to which it occurs in the animal kingdom, the origin and development of the parasitic habit, the evolution of the complicated life histories found among parasitic

forms, the effect of parasitism upon the parasite and upon the host, the relationship of parasitism to disease, and the factors of susceptibility, tolerance and resistance to parasitic infestations.

A parasite is an organism which lives at the expense of its host, giving nothing of value in return. The term parasite was first used to designate those individuals who frequented the tables of the rich and influential in ancient Greece and who courted these favors through fawning and flattery. The condition, then, has always been an opprobrious one.

The study of parasitic phenomena constitutes a special section of that new and at the same time extremely old field of ecology. It deals primarily with animal and plant associations, with the conditions and social relations which exist among living organisms. There can be no question but that it is as old and as universal as animal associations themselves. In any community numerous plants and animals live together and parasitism is an outgrowth of this association. Certain individuals find it easier, more pleasant and profitable to prey upon society than to earn an honest living.

The parasite may be a bacterium, a fungus plant or an animal. The bacteria are simple organisms with little morphological differentiation, characterized and identified by their metabolic or physiological reactions. They are primitively saprophytic, securing their food by the absorption of nutrient fluids, and consequently little modified by parasitism. The fungi, while probably derived from chlorophyll-bearing plants, have secondarily become saprophytic. Physiologically they are similar to the bacteria, and in both the effects of metabolism are analytic rather than synthetic. In a general way, therefore, the characterization of the bacteria may be applied to the fungi. The results of parasitism observed among the lower plants appear also in the animal kingdom, but in a more extended and amplified degree. It is here that the most conspicuous changes have occurred as a result of parasitism, that the clearest and most definite evidence is available for the study of parasitism as a biological phenomenon, and that the best opportunity exists to observe and measure its effects. Consequently the present discussion is chiefly concerned with parasitism as it occurs among animals.

For convenience we relate the parasitic forms in groups but frequently such groupings are not natural taxonomic or systematic ones. On the other hand they are in most instances ecological or physiological groups. The ectoparasites, endoparasites, temporary or facultative parasites have nothing in common except physiological attributes, and a classification based on these properties is obviously an ecological or bionomic one.

Parasitism in the animal kingdom is an almost universal phenomenon and no great group of animals is without its parasitic members. While there are relatively few parasitic vertebrates, aside from those belonging to the human species, the same is unfortunately not true for the invertebrates. Beginning a survey at the top of the invertebrate kingdom, a glance at the arthropods will show innumerable forms that have adopted the parasitic habit. The late Sir Arthur Shipley, in his recent paper, "Parasitism in Evolution," gives a splendid account of the parasitic insects. The lice and fleas constitute the subject of a large and special branch of entomology; the mites and ticks are minute arachnids without any external signs of segmentation; and these forms are augmented by enormous additions from the Crustacea. Living things from the largest elephant to the smallest rosebush are infested by the myriad parasites which belong to this phylum. Some of

the forms, indeed, are hard to recognize, since we find such extreme modifications in body form that the original characteristics are largely lost. Sacculina has become so modified as a result of parasitism that only a study of its life history demonstrated its true crustacean nature, and the linguatulids are so changed that even to-day there is much difference of opinion as to whether they are arachnids or polychaete annelids.

An astounding number of the worms are parasitic. Especially is this true among the nematode round worms. Hardly a species of metazoan animals exists which does not harbor some nematode species. Indicative of their prevalence is the recent volume of several hundred pages by Yorke and Maplestone on the nematode parasites of vertebrates. While the information is less complete, there is abundant evidence that the invertebrates are infested no less than the forms with a vertebral column. The majority of the flat worms are parasitic, and two of the classes, the trematodes and cestodes, are entirely so. These worms infest almost if not every species of vertebrates and their larval stages are frequently passed in invertebrate hosts. So far as we know all digenetic trematodes undergo parthenogenetic reproduction in some mollusk, while the cestodes frequently use other invertebrates as intermediate hosts.

Turning then to the most primitive phylum, the Protozoa, we find that every class has parasitic members and that one group, the Sporozoa, are entirely parasitic. It is estimated that there are no less than ten genera of parasitic sarcodinids, and an even larger number of parasitic flagellates; while the ciliates, usually regarded as independent, free-living forms, have a dozen genera that contain parasitic members. The Sporozoa is a group with no genetic entity, but consists of various sarcodinid and flagellate forms that alike have assumed the parasitic habit and reproduce by multiple fission. Actually it comprises a heterogeneous collection of forms of diverse ancestry which reproduce at some stage by sporulation. The Gregarinida and Coccidia sporulate at the end of a life cycle, have ectospores and manifest flagellate stages; the Neosporidia (Cnidosporidia, Sarcosporidia and Haplosporidia) sporulate throughout life from endospores and have amebic stages. The "binucleate" blood-inhabiting Protozoa are apparently descended from both (1) uniflagellate forms, originally parasitic in the gut of invertebrates and (2) heteromastigote forms, originally parasitic in the intestine of vertebrates. There are thousands of parasitic protozoan species described, and probably more as yet unknown.

Every species of animal harbors one or more parasitic species and the smaller parasites frequently occur in enormous numbers. With these data before us there can be no escape from the conclusion that there are more parasitic than free-living species in nature, and more parasites than free-living individuals. Such a conclusion may at first appear startling, but a careful study of the subject justifies the statement.

The next question to consider is why and how so many forms have become parasitic. There are really only a few basic conditions of existence, and as Schiller long since pointed out, "The edifice of the world is only sustained by the impulses of hunger and love." The most powerful animal instincts are those concerned with food getting, protection and reproduction. All these instincts are concerned with and involved in the development of parasitism. Animals must either shift for themselves or depend on others. They must have a source of food supply, whether they are herbivorous, carnivorous or parasitic. They may prey on plants or upon each

other. Animals in the same habitat strive for sustenance, for the means of existence. The stronger prey upon the weaker and the fittest survive. But there is another aspect of the picture. Some of the small and physically weak are able, for various reasons, to impose themselves on the stronger, and these cunning, socially clever individuals live at the expense of their neighbors.

Parasitism is a gradual and progressive adaptation to a dependent condition on the part of the animal or species which adopts this mode of life. It arises, at least in most instances, as a result of an attempt to secure either protection or food. In the end, the parasite obtains both from the host. The adaptation may be slight or very extensive. Certain species are temporary parasites, forsaking the host after a satisfying meal, while others become permanent dwellers near or at the source of supply. Other species are merely lodgers, deriving nothing more than protection from their host, with frequent transportation to new pastures as the host moves about. Then there is the condition of symbiosis, living together, either as commensals or mutualists. In the former case one species alone benefits by the association and the other receives nothing in return. In the latter case both benefit by the arrangement. It seems the usual trend of affairs, however, that when a species becomes a lodger, sooner or later it begins to attack its host, possibly when other food sources become scarce. Finally, to secure safer and more advantageous conditions of life, the ectoparasite penetrates into the body of the host.

External parasites can exist only in a fluid medium unless they possess a resistant, impermeable body covering. Aquatic animals may have soft-bodied ectoparasites, but if they leave the water, evaporation will cause these forms to dry up and die. To continue themselves, such parasites must either develop an impervious covering or enter the fluid-containing organs or tissues within the body of the host. For this reason the majority of ectoparasites found on terrestrial hosts are arthropods. In most cases the endoparasites have entered the host either through the oral or anal openings. Once inside the alimentary canal or one of its evaginations the parasite has found a veritable haven of refuge with a constant and abundant food supply. More often, however, when an aquatic animal leaves the water it loses its former parasites and acquires a new and different series of these predacious guests.

The adoption of the endoparasitic habit entails certain difficulties and dangers on the part of the species which assumes it. If the progeny of the parasite remains in the original host and continues to multiply there the life of the host is imperiled. Indeed, as Van Beneden long since pointed out,

> The parasite is he whose profession it is to live at the expense of his neighbor, and whose only employment consists in taking advantage of him, but prudently, so as not to endanger his life. He is a pauper who needs help lest he should die on the highway, but who practices the precept—not to kill the fowl in order to get the eggs. . . . The beast of prey kills its victim in order to feed upon his flesh, the parasite does not kill; on the contrary, he profits by all the advantages enjoyed by the host on whom he thrusts his presence.

The destruction of the host would be fatal to the parasite in question. In order that the parasitic habit may be successfully continued it is essential that the offspring of the parasite should leave the first host and secure new hosts, and incidentally this process of finding new hosts provides for the distribution of the species.

The life history of parasitic forms constitutes one of the most intricate and interesting subjects in the whole field of biology. As a rule, the parasite gives rise by reproduction to individuals which

pass out from the host. They may be cysts or eggs or larvae. These are the forms which constitute the infective stages in the life cycle of the parasite and which are concerned in the dispersal of the species. In certain instances, they reenter the original host species; in others, they attack different animals which serve as intermediate hosts. In any event, on leaving the primary host they are subjected to all the vicissitudes of a free-living existence. They encounter enemies and adverse environmental conditions. Frequently they are unable to take food and consequently must find a new host quickly or perish. Inadequately equipped to meet the exigencies of an independent existence, they largely succumb. The possibility that a particular larva will be able to survive and find a suitable host is extremely remote. Actually, in certain species not more than one in a million ever completes the life cycle. According to the estimate of Cort and his associates in the study of hookworm disease, each adult female produces on the average 8,830 eggs per day. In other nematode species, investigators report as many as sixty millions of eggs produced by a single worm. The liver fluke probably produces an equal number. On a conservative estimate, the beef tapeworm, *Taenia saginata,* produces 150 millions of eggs per year. In a balanced condition of nature, only a sufficient number of any species survives to replace the losses occasioned by death. Since the number of parasites remains relatively constant, each individual produces only one to succeed it. Obviously the mortality among parasitic forms is tremendous, and it is the hazard of the life cycle which introduces such disastrous consequences.

Frequently the dispersal stages of parasites are quite unlike their immediate progenitors. The Protozoa give rise to cysts, the Trematoda to ciliated larvae which resemble paramecia, and the Cestoda to microscopic six-hooked embryos. The protozoan cysts and tapeworm onchospheres are provided with resistant coverings and remain dormant, awaiting conditions favorable for development on the chance introduction into a suitable host. In other instances, the trematodes for example, free-living stages may be interposed. The parasitic stage produces a free-living one, which in turn either directly or by reproduction gives rise to individuals which infest the original host species or closely related forms. A third type of life history may be developed whereby the parasite is transferred from one host to the next by an intermediate host which acts as a carrier or vector. In this instance there are no resistant or free-living stages.

The complicated developmental cycles which exist to-day among parasitic forms can not be the original or primitive life histories of these species. In the long period of evolutionary development there have been innumerable changes in the relations between hosts and parasites. Former hosts have become extinct, and certain of their parasites, modified in form and life-history, have passed on to new hosts; the hosts may have become parasitic; or serving as food for other animals they may have carried their parasites into these species, where they have become established. Such a history has led to alteration of hosts and the interpolation of additional hosts; to metamorphosis and to peculiar types of metagenesis. The complex, intricate series of stages found in many life histories afford evidence concerning the course of events during past ages and the manner by which the parasitic habit has developed; but the character of the evidence, the complications, additions, omissions and reversals render an interpretation exceedingly difficult.

The question of the origin and development of parasitic life histories is a perplexing one, while the evidence is

fragmentary, obscure and sometimes contradictory. The student of vertebrate phylogeny has four sources from which he can deduce the past history of a species. Comparative morphology, embryology, paleontology and geographical distribution all contribute data which can be utilized in the determination of previous history. The parasitologist, on the other hand, unfortunately, has fewer and less definite sources of information. He deals with forms that have undergone adaptive specialization for their particular mode of existence, and this adaption tends to destroy primitive morphological features. Paleontological records are of course not available, for with rare exceptions parasites do not possess hard parts that would be preserved in a fossilized condition. Even geographical distribution is of slight and questionable value since there are various means by which parasitic forms spread from one locality to another. It is then in the study of the life history, and comparison between structure of the parasite and closely related free-living forms, that most of the evidence must be obtained. In cases of extreme parasitic adaptation such evidence is scanty. Living under relatively constant, uniform conditions, representatives of different phyla assume a superficial resemblance that may mislead even careful and experienced observers. The well-known tendency for animals of diverse ancestry to converge toward the same morphological type after living for a long period in the same environment is especially prevalent among parasitic forms. The adaptations to parasitism accentuate the likeness, and if no free-living stages are present in the life history it is well-nigh impossible to trace the ancestry and evolution of highly modified types. Additional complications arise when parthenogenesis and pedogenesis are introduced or interpolated in the life cycle. With sexual maturity of one of the larval stages, the primitive adult form may disappear entirely, and such elimination of the ancestral type multiplies the confusion. Frequently it is difficult if not impossible to determine whether certain existing forms are primitive or pedogenetic. While the elucidation of many life histories is difficult and present opinions are admittedly tentative, in cases where parasitic species have closely related free-living relatives, or in which larval stages have a free-living existence, positive conclusions may be derived with reasonable assurance.

The analysis of a few life histories taken from representative groups will illustrate these principles. Turning to the simplest organisms, the amebae, we find several harmless species which live in the intestine of various animals. Morphologically and physiologically they resemble free-living forms. Their vegetative stages occur in the intestine, and encysted stages pass out of the alimentary tract to be accidentally ingested by other hosts. In nature it must frequently happen that encysted stages of free-living amebae are ingested by various animals. In the intestine they find decomposing organic material, a limited supply of oxygen, and other conditions similar to those found in the bottom of the pond. It is easily possible for such amebae to spend considerable time in this environment. Some of them may encyst, and these stages, lacking motility, pass out with the intestinal content. Such a series of events will give us one of the harmless intestinal amebae as, for example, *Endamoeba coli*. This species acts as a scavenger, creeping about on the intestinal wall, ingesting bacteria and intestinal débris. A further stage in the development of the parasitic habit is manifested by *Endamoeba histolytica*, the pathogenic ameba of man. This species attacks the wall of the intestine where it frequently causes extensive ulceration. It feeds on the cells and red blood corpuscles of the host and after penetrating the intestinal

mucosa may enter the blood vessels of this region. The amebae are carried by intestinal veins to the liver where they produce hepatic abscesses, and Kofoid has submitted evidence to show that they may be carried to other parts of the body, giving rise to one type of arthritis deformans, and possibly also to Hodgkin's disease.

A similar series of events may explain the evolution of the flagellates parasitic in the intestine of various vertebrate and invertebrate hosts. A further modification and more complicated life history has developed in the case of the so-called binucleate flagellates, transmitted by insects and parasitic in the blood and tissues of vertebrates. Probably the most important members of this group are the trypanosomes, causative agents of certain recurrent fevers and sleeping sickness in man, and several fatal infections in lower animals. It appears reasonably certain that the trypanosomes originally were parasitic in the intestine of insects. In their life history there are three stages which correspond to the genera, Leishmania, Herpetomonas and Crithidia, respectively. These three genera may be free living, may occur in the latex of plants, or be parasitic in the intestine of insects. The primitive insects probably lived on plants or their juices. Some of the more plastic flagellates originally found in water or upon plants became accustomed to live in the intestine of insects. Later when these insects began to feed upon meat juices and eventually on blood, the flagellates in their intestinal tract gradually came to live in a blood medium. Entomologists are agreed that the acquisition of the sanguivorous habit by blood-sucking insects is recent and secondary. The flagellates in the alimentary canal of the insect, regurgitated while feeding, accidentally were introduced into the blood of the vertebrate and multiplied asexually there. The insect harbors the sexual stages and is properly regarded as the primary host.

The flatworms manifest all stages of parasitic adaptation. Better perhaps than any other group in the animal kingdom, they exhibit a consecutive series of stages illustrating physiological and morphological degeneration together with a corresponding increase in complexity of life cycle. The planarians are free-living, carnivorous forms. It is but a step from them to the monogenetic trematodes. These latter worms have lost their cilia, developed posterior organs of attachment and become parasitic on the skin and gills of various aquatic vertebrates. Their life history is relatively simple. The hermaphroditic worm produces eggs, which remain for a longer or shorter period within the body of the parent. An embryo, similar to the adult, develops in each egg and sooner or later escapes to become parasitic on the original host species. The digenetic trematodes constitute a separate group, not closely related to the Monogenea. The sexual stages are endoparasitic, occur in the intestine or body cavities of vertebrates, and produce eggs—each of which contains a minute ciliated embryo known as a miracidium. In all cases so far as known, this larva becomes free swimming, enters a mollusk, undergoes metamorphosis to form a sporocyst, and by a series of parthenogenetic generations produces cercariae—larvae of a very different type. These second larval forms leave the mollusk and directly or indirectly reach the original vertebrate host where they become sexually mature. The life cycle just sketched is typical, although there is much variation in the group.

Consideration of the life history just traced raises one of the most difficult problems in biology—the origin, status and meaning of the intermediate host. Did the original trematode ancestors enter vertebrates and have a life cycle without the molluscan host as believed by Looss and Mordvilko? Or as advocated by Leuckart and Sinitzin, did they first become parasites of mollusks and

later attack vertebrates? Yet more unlikely, did they attack vertebrates and mollusks simultaneously? Is their parthenogenetic reproduction in the mollusk a secondary and recent interpolation in the life history, or is the mollusk the original host—now reduced to the position of intermediate host? When and where did heterogeny arise? Did the mollusk formerly harbor the sexual stages of the parasite, or were these stages free living? All these questions have been discussed by able students of biology, and much difference of opinion exists. Even among those authors who believe that the mollusk was the first to be parasitized, and present evidence tends to support such a view, there is lack of agreement as to whether primitively reproduction in the mollusk was sexual or parthenogenetic.

The culminating stage of parasitic adaptation in the flatworms is found among the cestodes. Although their morphological features indicate their relation to the trematodes, they constitute a much more highly specialized group. Typically the cestode, or tapeworm, consists of a scolex or adhesive organ, a zone of growth, and a series of proglottids or segments. In certain species one or more of these parts may be reduced or missing. At no stage of the life history is there any trace of an alimentary tract. Single nervous and excretory systems supply the entire organism, while the muscular and reproductive systems are serially repeated in each segment. According to Leuckart the tapeworm is to be regarded as a colony and each proglottid as an individual. Such a view appears extreme, but actually it is impossible at the present time to determine with certainty which was primitively the anterior or posterior end. With rare exceptions the sexually mature tapeworms occur in the intestine of vertebrates. They have no free-living stages, the eggs pass out from the alimentary canal and are ingested by an intermediate host, either another vertebrate or an invertebrate. Ordinarily there is no multiplication in the intermediate host and accidental reentry into the original host with food or drink completes the life cycle. In the tapeworms of herbivorous mammals no intermediate host has been discovered, although presumably one exists. The recent work of Joyeux has shown that in certain species an intermediate host is unnecessary. Since there are no free-living stages, the interpretation of cestode life histories is exceedingly difficult. The questions which were raised concerning the origin of parasitism and the evolution of life histories among the trematodes may appropriately be applied to the cestodes. We can only conjecture as to whether the original hosts were vertebrates or invertebrates and how present life histories have been developed.

The nematodes manifest different types of life histories, and a study of parasitic adaptation as it has developed among these forms entails many peculiar problems. They have no near relatives and constitute an isolated and aberrant group in the animal kingdom. There are a very large number of species, some of which are free living, others parasitic. Many of the parasitic species have free-living stages in their life cycle, and it may be either the larvae or the sexually mature adults that live an independent existence. Frequently heterogeny occurs and a parasitic generation alternates with a free-living one. Keilin has recently attempted to prove that the free-living forms have been derived from parasitic ones and that such a history explains their morphological and biological peculiarities. Baylis, on the other hand, derived the parasitic from the free-living species. The worms are usually diecious. Females liberate either eggs or larvae. Frequently the larvae go through successive molts. Some develop

immediately and directly, causing heavy infestation; others require one or more intermediate hosts. Representative types of development may well be cited.

One of the best-known life histories is that of the hookworm. This nematode occurs in tropical and semi-tropical countries throughout the world. Authorities estimate that over a billion people are parasitized by hookworms. It is only thirty years since Looss, in Egypt, worked out the life history of the worm. His report was received with much hesitation—the story seemed too much like a fairy tale—but subsequent researches have confirmed his results. The adult worms live in the intestine and thousands of eggs are voided daily with the fecal material. If conditions are favorable, development proceeds and in a day or two the embryos hatch and enter the soil. They molt at the end of the second day and three days later are ready to molt again, although they may live in the loose skin for several weeks. At this stage they are infective, and if a warm-blooded animal touches the soil in which they lie, the larvae leave their sheaths and bore through the skin and tissues until they reach the lymph vessels or veins. They are then carried by the vascular system to the heart and thence to the lungs. In the lungs they leave the blood capillaries, enter the air sacs, migrate up the bronchioles and trachea, pass over the epiglottis, down the esophagus, and through the stomach to the duodenum where the migration is ended. During the period of migration there are two additional molts. The time required for development from the infective stage to sexually mature adults varies from four to six weeks. In this species there is a single host, a free-living stage and no asexual or parthenogenetic reproduction.

Another important species from the medical point of view is *Filaria bancrofti*, which is prevalent in all tropical countries. Adults live in the deeper lymph vessels and the larvae pass into the vascular system. These young worms swarm in the peripheral blood during the night, and mosquitoes act as intermediate hosts. After a developmental cycle in the body of the mosquito the larvae pass to the salivary glands, ready to enter a human being whenever the insect feeds. In Filaria there are two hosts, no free-living stages and no asexual or parthenogenetic generations.

A third type of life history is found in Trichinella. Adults live in the intestine; the larvae are discharged into the blood stream, distributed over the body, and eventually encyst in the striated muscles of the same host. Transfer to a new host occurs when infested muscle is eaten. In Trichinella there is a single host, no free-living stage and no asexual or parthenogenetic reproduction.

In the three life histories just given and in others, notably that of Ascaris, nematode larvae make extensive migrations through the body and tissues of their hosts. Frequently they pass by way of the vascular system. Other genera, for example, Onchocerca and Dracunculus, live in the connective tissues and regularly move about. Periodically they come to the surface of the body and may be felt in the subcutaneous areas. It seems probable that the frequent occurrence of such migratory habits among distantly related forms is of deep phylogenetic significance, although the exact meaning is not at all clear. We have no assurance that among the nematodes the stages of ontogeny correspond to those of phylogeny, and more information must be available before a final interpretation can be given.

Study of the life histories found in the several forms reviewed emphasizes certain common features. In general, all endoparasitic species must have some means of transfer from one host to another and usually it is accomplished by free-living, encysted, or other larval

stages. There seems to be no morphological reason for such migrations; they are extremely hazardous, and the phenomenon is necessarily one associated with physiological and life history requirements of parasitic forms. It is possible, as advocated by Moniez, that there are rejuvenating effects resulting from change of host and life in a different environment. Whatever explanation may be advanced to account for the development of the complex life histories of parasitic forms, it is certain that the changes have come about gradually as adaptive responses to new conditions. For that reason life history studies are of prime importance in tracing past history in any species, and the examples cited demonstrate the significance of larval stages in the elucidation and interpretation of present developmental cycles.

Undoubtedly parasites have existed since earliest times, and to a large extent the original species or their descendants have survived. Consequently it appears inevitable that parasitic forms have changed their character and their hosts with the passing of time, and these changes are responsible for the diversity of life histories now found among them. In certain species the sexual stages probably remain in the original hosts; in others they now occur in more recently acquired hosts. In many cases the later parasites made their appearance or transformation hand in hand with the evolution of their hosts. The parallel evolution of hosts and parasites has been demonstrated by many authors. Kellogg's studies on bird lice gave the basis for a natural classification of their hosts, and more recently Metcalf has traced a similar relationship between the amphibians and their opalinid parasites.

As a result of the long period of parasitic adaptation and the modifications of life history, characteristic changes have been wrought in the structure of the parasites themselves. It has long been recognized that parasites are descended from free-living forms. Among certain groups, notably the ectoparasites, there have been only slight physiological changes and little structural modification. Among others, especially endoparasitic types, there have been enormous changes in habits, in function and in physiological requirements. Accompanying and probably resulting from these changes, the species affected have been so modified that in certain instances they no longer resemble their free-living ancestors. The adoption of the parasitic habit usually results in a progressive reduction of the structures which function most vigorously in a free-living existence. The organs which render a species most alert and active, no longer used, undergo atrophy. Especially is this true of the sensory and locomotor organs. The parasitic flatworms have lost their cilia, fleas and lice have lost their wings, the scab mites are without eyes or organs of respiration, and the linguatulids are so highly modified that they have lost practically all of their primitive characteristics and superficially resemble tapeworms. With the degeneration of the sense organs and the muscles, there is a corresponding reduction of the central nervous system. As parasitic degeneration proceeds, one after another of the organ systems suffers reduction and ultimately disappears. Certain groups, of which the cestodes are a conspicuous example, have lost all traces of an alimentary tract. With such stupendous changes in the organ systems, there are corresponding modifications of body form. The mites and ticks are flattened dorsoventrally, facilitating close adherence to the skin. The fleas are compressed laterally and more readily slip through the hair. Beginning with species manifesting such slight changes, it is possible to construct a parasitic series illustrating progressive modification of body form until finally

the original structure is entirely obliterated. Sacculina is the classic example of such extreme degeneration.

Compensating for the reduction and loss of the organs which functioned during free-living existence, parasites have developed new structures adapted to serve different needs inherent in the changed mode of life. One of the first requirements is organs for attachment to enable the parasites to maintain their position on or in the body of the host. Various types of adhesive appliances have been evolved, ranging from the sucking disk of Giardia to the powerful suckers and hooks of the monogenetic trematodes. In almost every group one finds some sort of suckers or hooks or both. Not infrequently the new organs arise through the metamorphosis of primitive ones. Among the worms, modifications of the body wall at particular places have resulted in the formation of suckers. The hooks of many arthropod parasites are merely the vestiges of former appendages. The forms which live in closed cavities may be without adhesive organs, but in certain species at least the absence of such structures is regarded as secondary.

It is uniformly true that the luxurious idleness of parasitism—an inactive life with abundant nourishment—results in a very great over-development of the reproductive organs. As the other organ systems undergo regression, all the results of an active metabolism find expression in enormously increased sexual activity. Trematodes and cestodes produce millions of eggs. The culmination of this tendency is found among those highly specialized forms which have lost all save the genital organs and have become mere reproductive machines. It is the enormous fertility of endoparasitic species that has enabled them to overcome the disadvantages imposed by their complicated life histories and the transfer or alternation of hosts. Other factors, it is true, assist in this regard. Resistant coverings protect the larvae during unfavorable conditions and accessory methods of reproduction arise. Hermaphroditism and parthenogenetic multiplication, frequent results of parasitism, increase the number of individuals and the probability of survival. Not only is there hypertrophy of the reproductive organs, but among species that have become greatly modified as a result of parasitism, frequently asexual multiplication occurs between the sexual phases.

The excretory system is less modified as a result of parasitism than is any of the other organ systems. It functions in the elimination of nitrogenous wastes of metabolism, and the sum total of metabolic activity is not greatly influenced by parasitic life. Instead of expending its strength in locomotion, food getting and the other activities of free-living forms, the parasite utilizes its energy in reproduction. Unless the body form is considerably altered, however, the excretory system is not appreciably affected. Consequently, since it is a primitive, deep-seated and conservative system, in many instances it serves as one of the best clues to the relationship of parasites, not only between themselves, but also with their free-living relatives.

That parasites have harmful effects upon their hosts has long been recognized. It is almost inconceivable that an animal could harbor large numbers of parasites without serious and deleterious consequences. The best general statement to be found in literature concerning the influence of parasitism upon the host is that of Professor Henry B. Ward, published in *Science*, February 3, 1907. The clear conception of fundamental principles there portrayed has been demonstrated by the results of the last twenty years, while the analysis and conclusions presented stand out in stronger relief to-day than when the paper was written.

A consideration of the subject will show that the effects of parasitism depend on certain general or primary factors. Two of these are the size and number of the parasites. Other things equal, the larger parasites are likely to produce the most pronounced effects, although because of the action of complicating factors, in many instances this is not the case. Usually the larger parasites are found in the larger hosts; consequently their size, relatively no greater, is of no more significance. Ordinarily the single parasite has little or no influence; the presence of large numbers multiplies the effect and renders them dangerous. Not infrequently several parasitic species may infest the same host. As a rule, the smaller parasites occur in the greatest numbers. Thus the degree of influence exerted by parasites is largely determined by their size and number.

The consumption of nourishment by parasites constitutes a third general factor concerned in their effects. If abundantly nourished, the host may not suffer great inconvenience due to the loss of food material taken by its parasites. It is only when the food supply is limited, and just sufficient to maintain the life of the host, that the support of numbers of parasites becomes a serious drain upon vitality. In undernourished children the presence of hookworms retards or arrests development to a serious degree. Individuals of twenty years of age may have only the physical and mental development of a child of ten. It is a common observation that the presence of large numbers of parasites inhibits the development of the sexual organs; or if the parasites are acquired in later life they may so reduce the vitality of the host as to induce parasitic castration. An interesting sidelight on this subject is afforded by observations made in our laboratories. When animals are kept for a considerable period without food, the parasites of their intestinal tracts, deprived of food material, are able to maintain life, but their sexual organs suffer regression and temporarily reproductive activity is suspended.

Another primary factor concerned in the effect of parasitism is the location of the parasites. No organ is entirely free from parasitic infestation. Parasites may occur in the central nervous system, the sensory organs, bones, muscles, connective tissue, alimentary tract, lungs, liver, heart and vascular system, excretory and reproductive organs. If they invade an inactive or passive tissue it is obvious that the effects will be very much less dangerous than when the brain or some other vital part is involved and affected. Certain large nematodes may live for years in the connective tissue without any perceptible ill effect, while microscopic trypanosomes in the cerebro-spinal fluid produce sleeping sickness and lead to fatal results.

The effects of parasites may be classed as mechanical and physiological, although these categories overlap to a considerable extent. Naturally, severe mechanical injury must lead to physiological derangement. For descriptive purposes, however, the two may be considered separately.

Mechanical injuries arise through the obstruction of various canals. The blocking of the alimentary tract or of the ducts which lead from glands may produce serious results; such interruption of function induces stasis in the organs, pressure and sometimes even rupture of the parts. The presence of parasites or their products in the blood vessels may lead to the formation of emboli. Such foreign bodies in the circulation may interfere with the proper action of the valves of the heart or may obstruct the smaller capillaries, producing aneurisms in the brain or other vital organs. In other instances, for example, filariasis, masses of embryos obstruct the lymphatics, resulting in stasis,

edema, the formation of abnormal lymph sinuses, the enlargement of the parts and the production of elephantiasis.

Frequently mechanical obstruction or the activity of parasites leads to the formation of various types of lesions. The parasites may feed on the tissues as in the case of *Endamoeba histolytica* or the liver fluke. The destruction of any considerable amount of tissue would lead to diminished function and serious disturbance of physiological activity. The irritation resulting from these lesions stimulates cell proliferation and not infrequently leads to tumor formation. The most serious effects of lesions, and especially those produced by the migrations of parasites through the tissue, are due to the introduction of pathogenic bacteria. It has long been known that the ulcerations of the large intestine produced by *Endamoeba histolytica* allow the passage of bacteria into the submucosa and the blood stream. A common complication is the formation of abscesses in the liver, lungs and other organs. The frequent passage of worms through the wall of the alimentary canal permits or induces the entrance of bacteria into the body cavity and sets up general peritonitis. Laceration of tissue allows the entrance of bacteria into the blood stream and may give rise to general septicemia. Although there are histological changes in host tissues and many other results that properly fit in this category, obstruction of canals and production of lesions constitute the principal mechanical effects induced by parasites.

The physiological effects of parasitism, aside from deranged function produced by structural lesions, are due in large measure to the elaboration of substances which have a toxic action on the host. Certain of these substances consist of the ordinary excretory materials elaborated by the parasites as a result of their metabolic activity. The liberation of large amounts of these nitrogenous wastes has a profound effect on the physiological adjustment of the host. Another group of harmful substances comprise the specific toxins which are produced by particular parasites and cause particular reactions in the host. It is the production by trypanosomes of toxic substances which gives rise to various recurrent fevers and to sleeping sickness. These active principles have been extracted from the bodies of various parasites, and when injected into living organisms produce effects analogous to the symptoms of actual infestation. Specific toxic substances have been recovered from many of the parasitic worms, notably Ascaris and Diphyllobothrium. The toxins produced by this latter worm give rise to a progressive and extremely pernicious type of anemia, often associated with marked nervous disturbances. Frequently there is a combination of these two types of substances, excretory wastes and specific toxins, and it is difficult to determine whether the reaction is due to one or the other or both. Such a condition arises at the end of the reproductive cycle in malaria when the red blood corpuscles are ruptured and the melanin substance is liberated in the blood stream. The material is ordinarily believed to be derived from the destruction of hemoglobin; although it undoubtedly represents both—specific toxic substances and metabolic wastes. An additional category of toxic substances are those produced by the death and disintegration of the parasites, by the anaerobic and fermentative decomposition of organic material. Not infrequently dead parasites are the most dangerous. The decomposition of the parasites may result in the formation of particularly virulent products.

The presence of these foreign substances in the body of the host leads to marked changes in the character of the blood. Certain of them destroy red blood cells; others induce different blood

changes. The nature of these substances and the method by which they act are as yet almost entirely unknown. One of the first recognizable effects is an increase in the number of eosinophile leucocytes, and the increased number of these cells in the blood corresponds with the intensity of infestation. Consequently, eosinophilia may be regarded as a diagnostic feature of parasitic infestation.

The substances elaborated by certain parasites cause such changes in the blood that its ability to coagulate is inhibited. The secretion produced by the salivary glands of hookworms prevents the coagulation of blood, and hookworm lesions in the intestine bleed profusely. Serious anemia may be caused by a half dozen hookworms, and a common test of hookworm infestation is to measure the amount of hemoglobin in the fecal material. By this means it is possible to estimate closely the number of hookworms in the intestine.

The factors involved in the degree of susceptibility and resistance to animal parasitism are as yet only partially understood. It is generally appreciated that young animals are more susceptible to parasitic infestations than adult individuals. It has been suggested that the older individuals are refractory because of resistance developed as a result of some previous infestation, possibly slight and unnoticed. Careful and controlled experiments have proved, however, that the age factor is of importance, irrespective of previous infestation. In test cases where prior history is known and it is certain that the subjects have not been previously parasitized, young animals may be infected while adults of the same species resist infestation. Young animals that are susceptible develop increased resistance to infestation as they grow older. The basis of this reaction is chemical, but we have no precise knowledge as to the factors concerned in the development of this resistance.

It is generally agreed that species or races which have harbored a given parasite for a long period of time show less marked effects as the result of its presence than species that previously have not been subjected to such infestation. In most instances, however, infestation by animal parasites does not give rise to immune reactions such as usually result from bacterial infection. Agglutinins, precipitins and lysins do not develop, or at least do not become effective for animal parasites. The immune substances developed in response to bacterial infections render such diseases self-terminating, whereas a parasitic infestation may persist for many years. Ordinarily an individual can be reinfested over and over again. In the case of animal parasites, defense reactions, comparable to those against bacteria, are not developed. It is certain that the blood is modified and that the presence of parasites may be detected by serological tests; but the study of defense and immunity phenomena has not progressed so far in the case of animal parasites as in that of bacteria, and the field of serological investigation is one of the most promising for future work in parasitology.

Parasitology is not, as has sometimes been supposed, a narrow or highly specialized field of study. It is, on the contrary, as wide and general as biology itself. The student of animal parasitology deals with every phylum from protozoans to mammals. No one can undertake an extensive study of any group, either animal or plant, without sooner or later encountering parasites and their effects. A consideration of parasitism, therefore, properly enters every field of biological inquiry whether the study concerns morphology, life history, physiology, ecology, pathology, genetics or evolution.

THE AWKWARD CONSISTENCY OF SCIENCE

By Professor JOHN A. ELDRIDGE

DEPARTMENT OF PHYSICS, THE STATE UNIVERSITY OF IOWA

COMMON sense is the mother of Science. When the first philosophers ventured into a more exact inquiring into natural law than was necessary for mere existence, Science was born. Young Science discovered many things, none of them exactly true, usually things compatible with common sense. As Science became older, its laws became firmer and truer and stranger.

But even when learning its first faltering steps this infant, nursed by the philosophers, seemed a daring child. Not always were its theories the outgrowth of general knowledge. Sometimes they were the product of unbridled imagination. Such over-ambitious attempts to read the riddle of nature usually ended in fallacy. Many of the results of the earliest scientific speculations are buried in now forgotten mythologies; in later times the more daring adventurers in scientific thought conceived of astrology and alchemy and spiral cosmoses. The earliest adventures in extrapolation were unhappy.

But as Science has grown older and tried its laws have become more rigid and trustworthy, and it now ventures with much assurance into valuable extrapolations from the known into the unknown. As the scientific law has become reasonably sure the scientist bases his whole faith in it, and by consistent reasoning ventures into new theories of which common sense can never dream. Common sense is apt to classify things in a subjective manner. The fundamental concepts of common sense are things important to ourselves, such as three meals a day, the number of miles to a gallon and the price of soap; very important things to know about if we are to live happily. Science classifies objectively; the fuel value of gasoline and the affinity of molecules and the laws of electronic attraction are considered together as related concepts. Common sense teaches us that the sun rises once a day; science teaches us that the earth goes about the sun attracted to it by that same law by which the sun is (to a very unimportant extent) attracted to other suns. Common sense sees only the important; science recognizes only the consistent. The irresistible consistency of science often leads to concepts of nature from which our common sense revolts.

Common sense told our forefathers that the earth was flat, as of course for practical purposes it was; a slight change in the position of a star told the scientist that it was round, and Columbus discovered America. We all know that bodies fall down to the earth; Newton, treading the path of consistency, maintained that the earth also fell up to the body, and he explained the solar system. Common sense tells us that now is now whether we are moving or whether we are at rest; Einstein inquired as to the meaning of now and discovered relativity. Common sense tells us that a straight extension either of time or of space never retraces its path; the scientist is not so sure, and follows out his argument with a consistency which would be very awkward for common sense were common sense not fortified as always by its sublime consciousness of being right.

But let me illustrate by a simple example the fanatical consistency with

which the scientist follows his law. A reasonably sure law is Hooke's law of elasticity. If we have a metal bar and pull it, the harder we pull it the more it will stretch; bending it, the more the bending force the more it will bend. Good science and good common sense. If we have a steel railroad rail between two ties, the rail will undoubtedly bend as the train passes over it; with half the load the bend will be half as much; if we push it but gently with the hand it will bend, little, it is true, but still bend. Here common sense begins to hedge, but it is true. Such delicate instruments has science given us that even the slight touch of the hand produces an effect which is easily observed. Similarly, if a fly alights on the rail, it will bend. True the fly has but a billionth the weight of the car wheel and now the rail will bend but a billionth as much, but still it will bend. We do not really believe it but if one fly will not bend it, neither will two or three, nor can a train bend it. The difference is only between the important and unimportant. This illustrates what I mean by the awkward consistency of science; common sense neglects forces when too small to be important; science can only understand the larger force by remembering the smaller. The old soothsayer who first conceived of the straw which broke the camel's back had this consistency of the scientist.

The most famous propounder of awkward questions was Socrates, and indeed the difference in the point of view of the scientific observer of nature and the common user of nature is just the difference between Socrates with his annoying questions and the Athenian fish merchant with his edible merchandise. We may let a very modern Socrates be the spokesman for science and the fish merchant uphold common sense in a Socratic dialogue.

Socrates accosts his fellow citizen: I would a word with thee.

Fish Merchant: What do you think of fish to-day?

Socrates: Have you heard the latest word from the laboratory, that a fish is only a wave in space?

The fish merchant illustrates the new theory by continuing to fill space with his cries, Fish! Fish! Fish! But Socrates, being Socrates and utterly devoid of common sense, collars the fellow and the following dialogue ensues.

S. So you think a fish is only a fish; so as we look about we see many things which seem very simple. Before us we have a fish; it is an object and you know just where it is. Here fish, there no fish. It has its place in space where no other fish can be, it has weight and inertia and you know just where these are located. You think that no one but a foolish philosopher would cast doubt upon your knowledge of the existence of that fish. But the scientist, who is much better loved to-day than the philosopher, loves consistency no less than he and the scientist is indeed very much worried about just this question.

Now the fish merchant had spent all of his days in fishing and rather resented the superior knowledge which Socrates assumed to have in regard to the subject. When he had remarked as much, Socrates replied: Well said! Let us look then to a more neutral subject. Fish are but little favored in philosophic or scientific demonstrations. Consider a billiard ball on a table. I can specify its position very well by its center and so we will say that the ball is there. If the ball be gently pushed this center will change its position, going faster and faster. Were we to compare steel balls, iron balls and cork balls we should find that some balls gained speed more slowly than others; we say that they have more inertia or mass. This mass is just a number which we give to the ball to indicate the difficulty of moving its center; we need not worry for the moment about

where it is; it belongs to the ball just as your bank account belongs to you.

F. M. Now wait a bit, old man. That billiard ball isn't located at a mathematical point but is a real object, a sphere about an inch in radius. And its mass is located where *it* is.

S. I am willing to agree. It has more reality than an imaginary point near the table. It is an object and extends about an inch in every direction from the center of gravity. But how do you know?

F. M. I can feel it, I can handle it. Indeed so long as my finger is several inches away from your mathematical point the ball does in no way affect my finger; but let me come approximately an inch from it and the ball pushes back. Or if two similar balls were on the table those centers could never approach nearer than two inches. I say the ball is wherever it can affect other bodies.

S. Spoken like a philosopher and a scientist! A great philosopher once put forth as his only dictum "*Cogito ergo sum.*" I like your definition of existence better. "*Facit ergo est.*" It acts therefore it is. Your ball is wherever it acts. Where it exerts a force there it is. Or perhaps you would rather test it by sight; where it looks to be there it is.

F. M. No; let's leave the sight out of it. I know about your optical illusions. Feeling's believing.

S. Excellent; we can always tell where an object is by the fact that it exerts a force upon another body if it attempts to occupy that position. So much for common sense, now for logical consistency. Let us talk of lighter objects. What of water?

F. M. An object, but a stranger one. It does not keep the same shape. It will part and let my hand enter it and yet we can tell where it is by the same test. At some places my hand is not affected and at others my hand is pushed back. Wherever it acts there it is.

S. Excellent. And air? Is air something real or not?

F. M. A yet stranger object, but it is real.

S. Yes indeed. The test becomes more difficult. The ancients were not so sure of the materiality of a gas, hence the name gas or geist or ghost or spirit. Yet the presence of a gas is after all quite apparent—a rapid sweep of the arm meets resistance; a strong wind impresses us with the reality of this object. The mass is smaller, the object beats an easier retreat as we approach; yet it is very real.

But now, O worthy fish merchant, suppose I rub those billiard balls with a bit of wool; the balls now are electrically charged and the two similarly charged balls repel one another though their centers are many inches apart.

F. M. Yes, I have heard of this action at a distance and it has puzzled me greatly. How can a ball exert a force on another at a great distance from itself?

S. How, indeed? You tell me that a thing is wherever it acts and now you ask me how it can act where it is not! This is not a mystery of nature but a mystery of logic. Will you no longer cling to your meaning of existence? *Ubi facit, ibi est.* Where it acts there it is.

Oh the inconsistency of common sense! The ball pushes back on another ball; where it pushes there it is. The charged ball pushes back on another ball, but now it pushes where it is not. How strong must be the force before you believe in the reality of the object?

F. M. This is not the kind of push I meant. This electrical pushability of charged bodies extends in lessening degree everywhere; it is not the kind of force I meant. The existence of an object is betrayed by a suddenness of push when we touch it, which is very unlike this electrical force. Two inches away, an inch and a half, an inch and a hundredth, however little more than an inch away from the unchanged ball we are, there is no effect whatever; at an inch

distance the push suddenly begins. This is the space-occupying property which betrays the position of mass. That other kind of push is only the electrical field which we all know acts at a distance. The electrical field is too gentle, comes in too gradually, is too easily penetrable, to be a body; a material body always has a definite edge, at least always except in the case of gases.

S. An argument for the Sophists! You know where a body is, therefore it can not be somewhere else, least of all throughout all space! Well let it go for the moment. Now let me speak of something else of which I know more than you. All things, even fish, consist of molecules, atoms and finally of electrons and protons. Let us consider the least massive of all these, the electrons. An electron has mass; if it strikes a molecule or atom or other electron, it will push it back as a fast-moving ball does another ball. But these electrons are pure charge; they are like the charged billiard ball without the ball. They repel one another at great distances. The closer they come the greater the repulsion and this is all there is to it. Where are these electron objects? I should say, wherever they act. I should say that they extend in very unimportant intensity to the greatest distances in space. This is the awkward consistency of science.

But you do not want to consider this electrical force as locating the object. This is common sense. You want the electron to be where it "really is," not everywhere all over space where it isn't but happens to act. I do not understand. If this electrical repulsion is not a symbol of a real object to you we must agree that in your sense the electron is not an object because so far as we know this is the only force it can exert.

As with the electron, the elementary negative charge, so with the proton, its positive conjugate. And all atoms are made up of electrons and protons and all bodies are made up of atoms.

If a ball pushes back on your hand when you touch it, it is because the electrons or protons in ball and hand are repelling. Here as truly as in charged bodies the forces act at a distance, only the distances are very small, about a billionth of an inch. Beyond this the forces still exist, but they are really too small to be important. I am afraid if you do not accept these electrical forces as a symbol of the existence of an object that no object will for you ever exist.

What a dilemma! You don't believe that the thing you call ball extends, even in the slightest degree, everywhere. Yet where will you stop and say this much force makes an object; less than this is nothing? Oh the awkward consistency of science which insists on sticking to a definition!

At that the fish merchant winked and proceeded: It sounds philosophical but of course you and I both know it isn't so. We know that these balls are right there where they are.

S. In the important sense you are right. Most of the mass of the ball is right there very close to the electron and proton centers. The scientist sees all mass as electromagnetic and located about the charge centers, but even in the case of the charged ball where the electrical field extends to great distances the amount of mass in this external field is out of all proportion small in comparison to that between the multitudinous charges in the one-inch sphere. You certainly catch the most important part of the fish in your net. So you have the fish but I have the logic.

The fish merchant smiled a superior smile as though contented with this division and Socrates continued:

I see that you regard me as a hopeless philosopher arguing about the existence of nothing. You think my tenuous, all-pervading mass is of no consequence. But indeed without it all things are not. Let me mention another object which is equally tenuous, yet so important that

it can not have escaped your observation. I refer to light. Tell me again what you mean by a material body.

F. M. It is something which exerts a force when it is stopped; you can feel it when you punch it.

S. And so with light. It has little mass, it is true. Indeed so little that as I hold my hand out stopping the sunlight, I can not feel the pressure; but it is there. Perhaps you have seen in the jewelers' windows the radiometer, a device with vanes which rotate when the sun shines upon it. The action is complicated, but if all the air be removed from such a device and it be mounted more delicately it can be shown that light falling upon it produces a pressure, as does a ball striking a bat. If this is your test of materiality, and I believe it is the best possible one, light has mass. Very little, it is true, and yet some. All the light striking upon Greece during a minute of a summer day has a mass of about one ounce. It comes so fast that the total pressure it produces is considerable—about a quarter of a ton. The sun is continually losing mass—millions of tons per second—as it gives off light. Because of this light pressure, the tails of comets are seen to be pushed always away from the sun. Yes indeed, light does produce a push when it is stopped, and so it is material. Of course this pressure is too little to be felt by the hand and so all this is contrary to common sense. These things seem unimportant; as to what its fundamental significance is in the building up of universes you must ask the astronomer and perhaps he will tell you that nothing is more important.

F. M. That may be so, but sunlight is certainly not material just the same. Indeed, it fills all space where we know there is nothing. And if it be something why should it not fall back to the sun by gravitational attraction like everything else?

S. It does fall back but not very much. As it leaves the sun it loses some of its speed. But so great is its speed that it has no difficulty in getting away. Experiments several years ago to test the theory of relativity showed that starlight in spite of its high speed, was bent by attraction as it went by the sun. Again and again science following consistency faithfully reaches results which are contrary to common sense.

Were there time, I could tell you about the conservation of mass, how the moving electron grows heavier as it takes mass out of the field which makes it move, how stopping it gives off light and loses mass. I could tell you of some of the mysterious motions of this mass field in the atoms. I could tell you how science makes a consistent cosmos out of wave motions in space.

F. M. Well, goodbye Mr. Socrates, and it has been interesting; but just as between your mass and mine, yours may be as flighty as you wish but mine is all here.

With that the fishmonger went down the street selling his wares, and the modern Socrates went back to his problem of making artificial light more economically.

THE SPOOR OF A THUNDERBOLT

By Dr. STERLING B. TALMAGE

ASSISTANT PROFESSOR OF GEOLOGY, NORTHWESTERN UNIVERSITY

MOST normal American males have experienced in some degree the thrill of following a trail through the wilderness. The boy scout has as a specific assignment tracing the course of a companion wearing "tracking irons." The trailing of small game through the snow is an annual delight to the country lad. Following the spoor of big game is something most of us read about enviously, though few of us are able to do it. But it is a rare opportunity that permits a man to follow through the forest the trail of a flash of lightning for a distance of eighty-five feet, over rocks, sod and soil, through underbrush and dead timber, from near the top of a hill to the shore of the lake at its base.

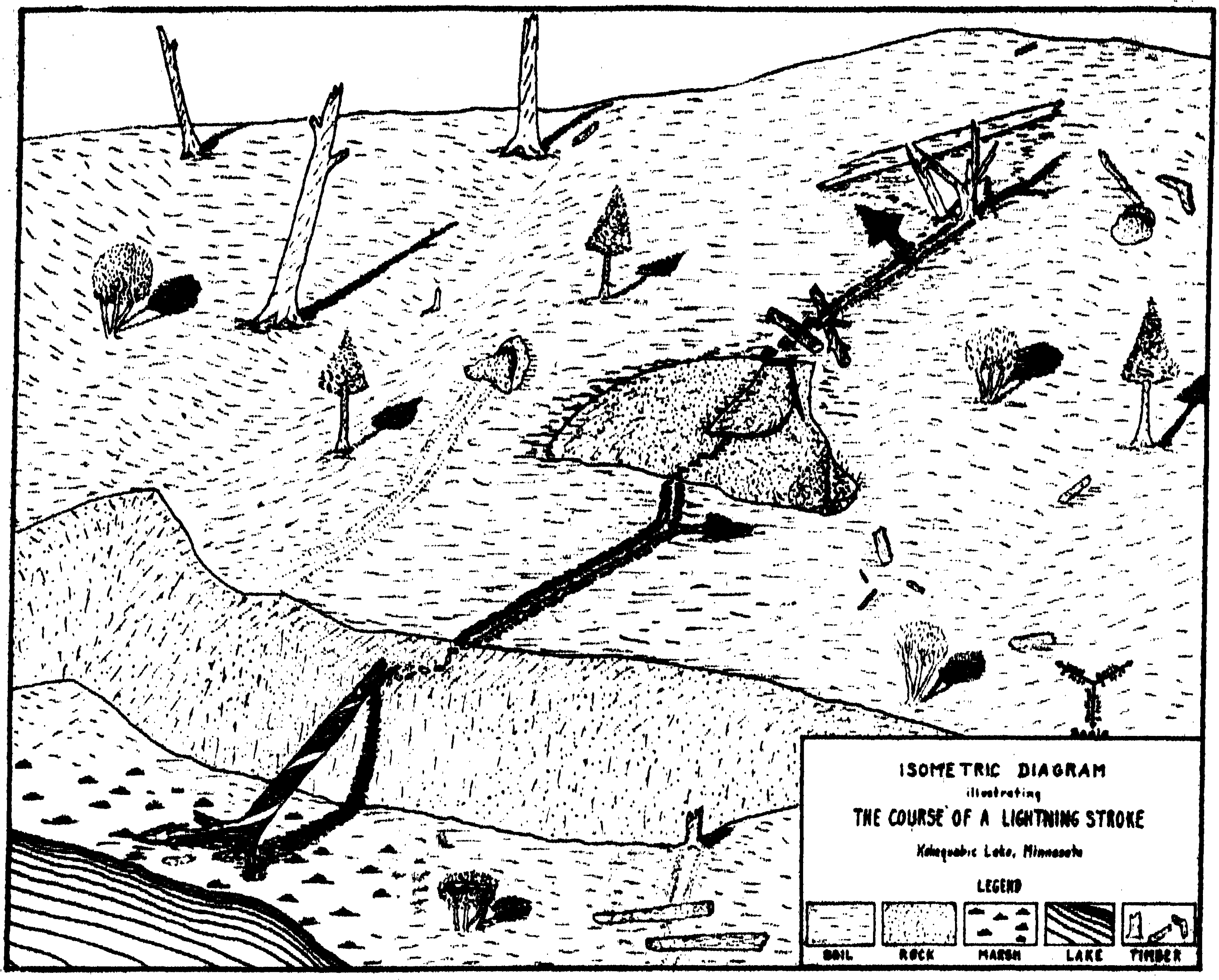
Such an opportunity was unexpectedly encountered by a party of Northwestern University geologists, under the leadership of Professor U. S. Grant, while in their summer camp on Kekequabic Lake in northern Minnesota. The region is one of numerous lakes, separated by low hills, some of which, however, are steep and rugged. These hills were formerly clothed with a dense growth of pines, but forest fires have killed the big timber; at present the hills have a thin soil cover that supports a rather dense undergrowth. The remnants of the older forest consist of charred stumps, fallen logs and a relatively few standing trunks, now dead, twisted and bare of bark, some of them projecting as much as fifty feet above the undergrowth.

An island in Kekequabic Lake escaped the later fires, and on this wooded island the party camped. The hillside to the north of the lake is as described above; it was of particular interest to the geologists because the deforestation had resulted in several splendid rock exposures which under forest conditions would probably have been buried by soil and vegetable mold.

A dead tree standing near the top of the hill was the "lightning rod" that led the electric discharge from the clouds to the ground. Unfortunately, the lightning was not seen to strike, but its time can be fixed within forty-eight hours. On a Tuesday two members of the party had found some very interesting rock exposures on the hillside, and had noted a prominent dead tree to serve as a landmark. On Wednesday and Thursday the whole party was working at the west end of the lake, and both these days were marked by intermittent thunderstorms. On Friday the entire party went to the north side of the lake to observe the features noted on Tuesday, and were puzzled by the absence of the landmark; it was found that the tall dead tree had been completely wrecked by a lightning stroke on one of the preceding two days.

The accompanying photograph shows the shattered stump and the fallen trunk beside it. The ground was disturbed from the base of this stump down nearly to the lake shore, but much of the line of disturbance was obscured by underbrush so that it could not be photographed. Therefore the accompanying sketch has been prepared, based on photographs and measurements, but drawn so as to show the features by which the course of the lightning could be traced, without including the obscuring underbrush.

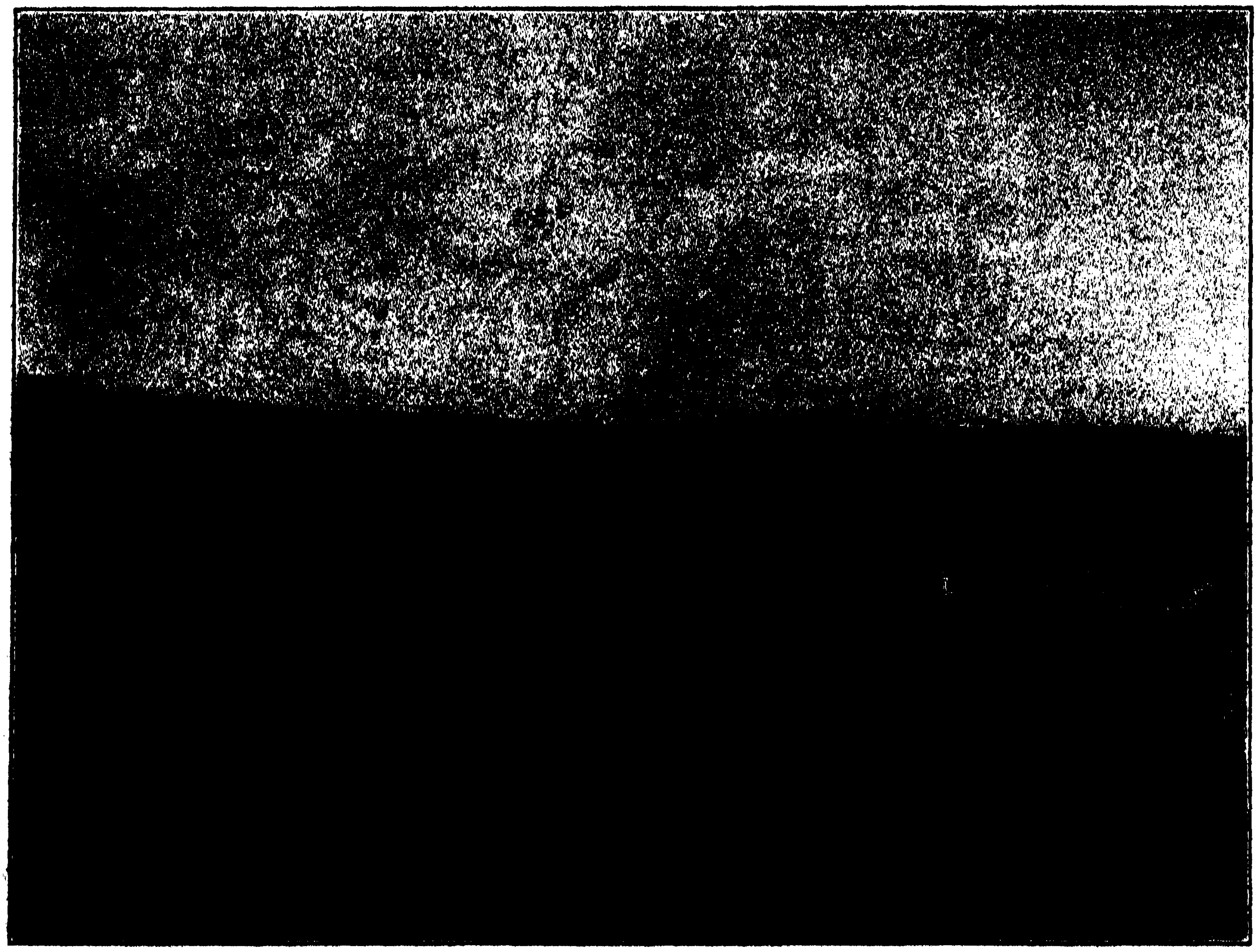
The tree that was first struck was shattered near the bottom as though by an explosive. The standing stump, nine



feet high, was split and riven to the core, but with pieces six feet or more in length flaring outward from the middle, but not completely broken away. A portion of this tree some thirty feet in length lay prone on the hill alongside the shattered stump; this fallen log was badly scarred and split, though not so completely shattered as was the standing stump. On the ground nearby lay numerous fragments of newly split wood, and such perfectly fresh chips could be found in diminishing numbers to a distance of nearly a hundred feet in all directions.

From the base of this stump and extending for sixteen feet directly down the hill, was a freshly turned furrow, about the size that would be made by a standard plow; a small pine tree about six feet high had stood at the edge of this furrow, and had been half uprooted and completely overturned to the west. At the lower end of this furrow were two logs, lying across its course; in line with the extension of the furrow these logs had been freshly charred on the surface. For six feet farther on small blocks of rock showed a distinct line of disturbance.

These small rock blocks, which had been moved from six to twelve inches out of their places, formed the somewhat broken upper surface of a bedrock exposure that extended about twenty feet down the hill and much farther than that along the hillside. At the lower end of the line of broken small blocks, a large block, measuring two by three by five feet in greatest dimensions and weighing something over a ton, had been moved bodily a distance of four inches to the south. At the upper end, where this block was thickest, it showed a clean break, and at the lower end, where it tapered down to an edge, it projected over the bedrock surface.



VIEW LOOKING WEST ACROSS KEKEQUABIC LAKE

SHOWING ISLAND ON WHICH PARTY CAMPED; THE NORTH SHORE OF THE LAKE, SHOWN AT THE RIGHT OF THE PICTURE, WAS THE SITE OF THE TREE THAT WAS STRUCK BY LIGHTNING.

The upper surface of this moved block showed no trace of the lightning effect, but from under the lower edge there were two lines of disturbance; about six feet southeast of the edge of the moved block the bedrock disappeared under a thin covering of soil, which a thick growth of grass and moss had knitted into a compact sod, resting directly upon the rock. This sod carpet, still showing fresh on the under side, had been folded back over an area measuring three by five feet, much as a rug might be folded double by pulling back the corner; this folded-back sod marked the end of the trail in this direction.

The main trail of the lightning went from under the edge of the moved block directly downhill, where for a distance of eight feet the surface of the bedrock was chipped and flaked, exposing patches of fresh rock that made a marked contrast with the weathered and moss-grown rock surface. In the loose soil farther down the hill was another furrow, perfectly fresh and but slightly smaller than the furrow that began at the base of the stump farther up the hill.

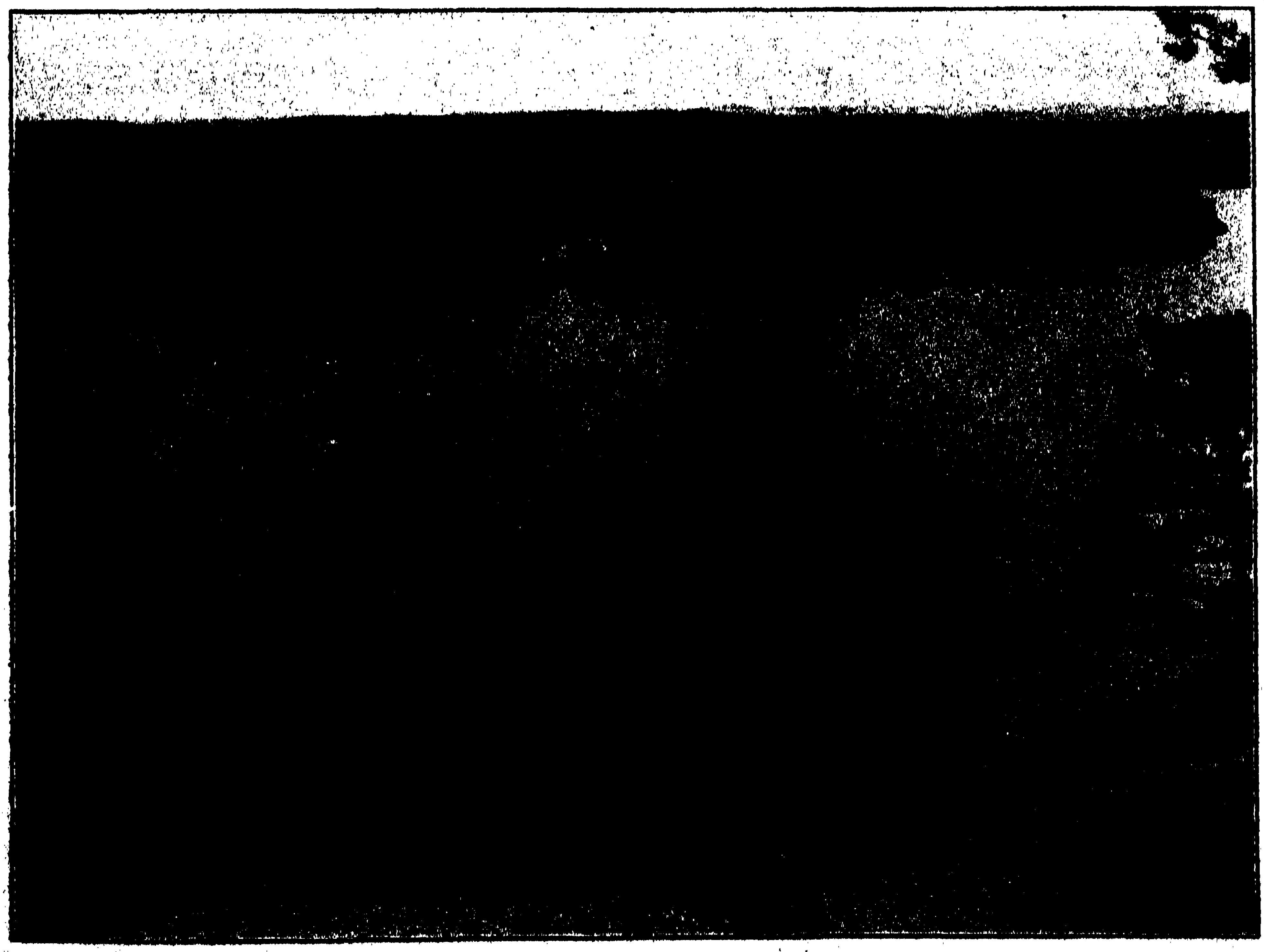
This lower furrow ran for about six feet southeasterly to the base of a small pine tree, which was overturned to the east; the furrow continued directly down the hill (nearly south) to the top of a fifteen-foot cliff that stood above the marsh at the edge of the lake.

In this marsh was a dead tree about eighteen feet long; this tree had fallen back against the cliff, a rocky projection of which had caught the tree about two feet below its top. From the lower end of the lower furrow, described in the last paragraph, to the point where this tree

rested against the cliff was a line of freshly broken and chipped bedrock quite similar to that seen on the rock above. The tree was scarred spirally in a striking manner; from the point where it touched the cliff the lightning had evidently followed the grain, and in this species of tree the grain is much twisted. A band of freshly scarred wood passed three times around the tree in the sixteen feet that lay below its resting point; the two feet above the point of contact with the cliff was not scarred at all. The contrast between this white scarred surface and the gray weathered surface of the wood was so marked as to give the tree something of the striped appearance of a barber's pole.

The grain that was so scarred was in line with one of the larger roots that remained buried in the bog. At the point where this root entered the bog, it again appeared that an explosion had occurred. The root was completely shattered, and apparently burst from the inside outward. Here, it seems, the lightning flash was finally grounded, after passing over rock, wood and soil for a distance of eighty-five feet from the base of the shattered stump first struck.

On first observing some of the disturbances on the lower part of the hill, one found difficulty in believing they were due to the same lightning that struck the tree above, but after tracing out the whole course, foot by foot, no doubts remained. The observer was left with a new appreciation of the tremendous power manifested by a lightning flash, and with a profound respect for the term "thunderbolt." This term, still sanctioned as good usage in describing a flash



VIEW LOOKING NORTH ACROSS KEKEQUABIC LAKE

SHOWING ISLAND ON WHICH PARTY CAMPED, AND BEYOND THE ISLAND THE HILL ON THE NORTH SHORE ON WHICH WAS FOUND THE SPOOR OF THE THUNDERBOLT.

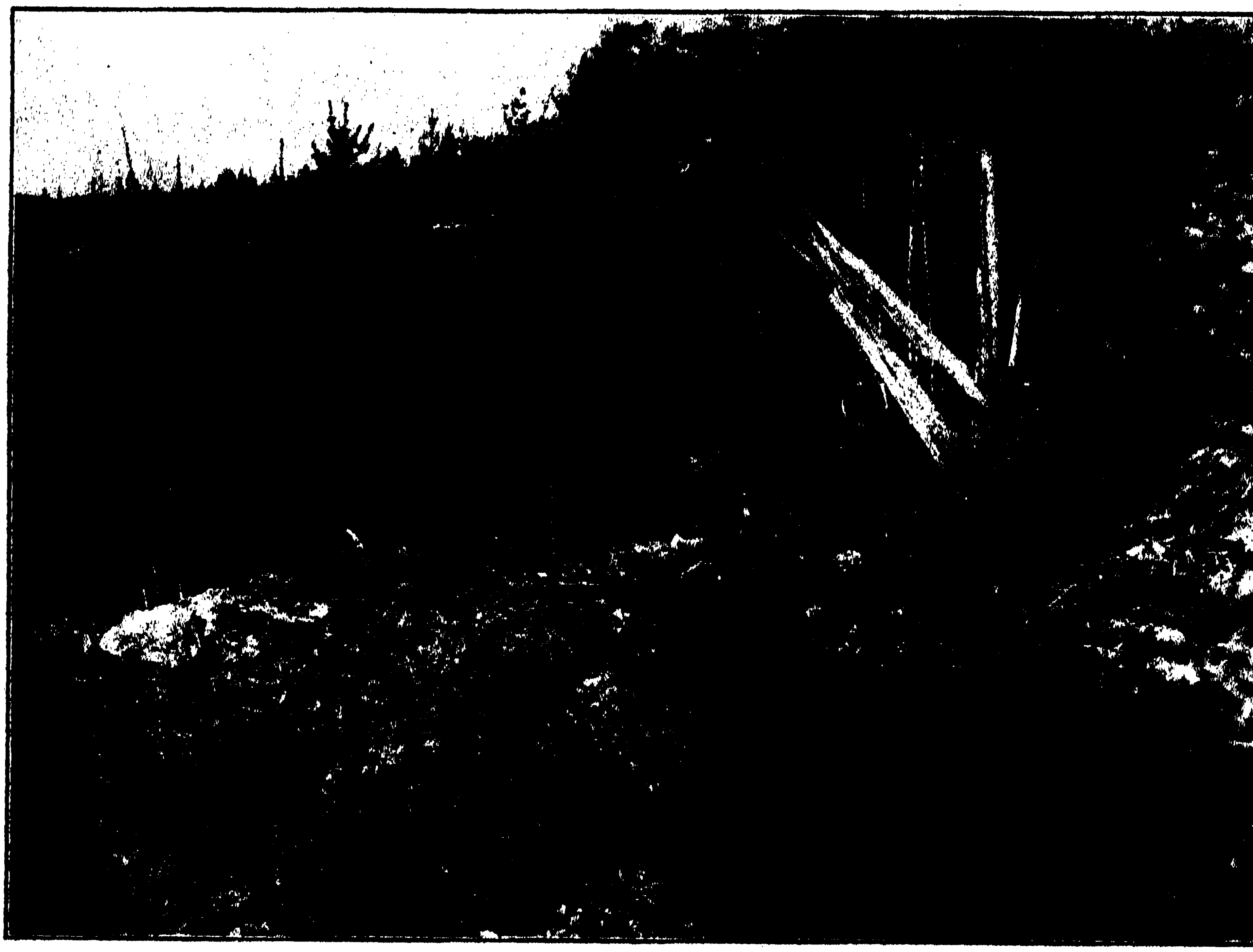


PHOTO OF TREE THAT WAS STRUCK BY LIGHTNING

NORTH SHORE OF KEKEQUABIC LAKE; THE PATH OF THE LIGHTNING STROKE WENT CLEAR ACROSS THE GROUND SHOWN IN THIS VIEW, AND MOVED THE ROCK BLOCK, SHOWN AT THE EXTREME LEFT, A DISTANCE OF FOUR INCHES.

of lightning that strikes the ground, is a relic of the time before Franklin announced that lightning and electricity were the same thing, when "the notion prevailed that a solid heated mass passed along the lightning flash and buried itself in the ground." (Standard Dictionary.) The term "bolt" as used in those days did not have its present acceptation; but rather signified an arrow or projectile; in to-day's language "thunderbullet" would better express the original meaning.

If some philosopher of Franklin's time, before the performing of the famous kite experiment, could have been transported to the north shore of Kekequabic Lake to see what the writer has described, he might have speculated at length on the character of the thunder-projectile. Was it like a great axe, as the tree at the top suggested? Was it like a plow, to turn up furrows that were straight and deep? Was it like a wedge or lever, to pry a ton block of rock loose from its place? Was it like a chisel, to chip and flake the bare rock surface? Or was it like a roughing plane, to follow the grain around the tree at the bottom of the hill? Certainly, it looked as though something solid had passed through and torn things up; it is small wonder that it took a long time for men to recognize the relationship between lightning and the galvanic battery.

The observer of to-day, used to electricity as a commonplace factor of his daily life, is also led to speculate, but along a different line; he asks, How could the passage of the electric current

produce such effects, and why should the current follow that line, instead of being grounded at the base of the upper tree? The following explanation seems both simple and satisfying.

Electricity is known to pass along the line of least resistance. A lightning rod, a spire or a tree that is struck is a better conductor than is the air. Dry wood and dry earth are poor conductors; moist wood and moist earth are better, and consequently when a conductor is once grounded no further effects are generally visible.

The hill north of Kekequabic Lake, however, is composed of solid rock, except for a thin soil cover over part of it; this soil cover, moistened by the recent rains and partly dried at the surface by the intermittent summer sunshine, would furnish an interrupted layer of moist earth on the surface of the bedrock that would be a better conductor than the bedrock itself, and consequently would lead the electric charge downhill instead of directly into the earth at the first point of grounding.

This suggests an explanation for the unusual course of the current, but what about the character of the disturbance? Again the explanation seems simple and logical. Moist wood or moist earth, while the best conductors on that hillside, must still be ranked as poor conductors in comparison, for instance, with metals. Whenever electricity passes through a conductor it generates heat, and the poorer the conductor the greater the heat generated by the passage of a certain current. The generation of considerable heat in a moist medium would naturally transform that moisture into

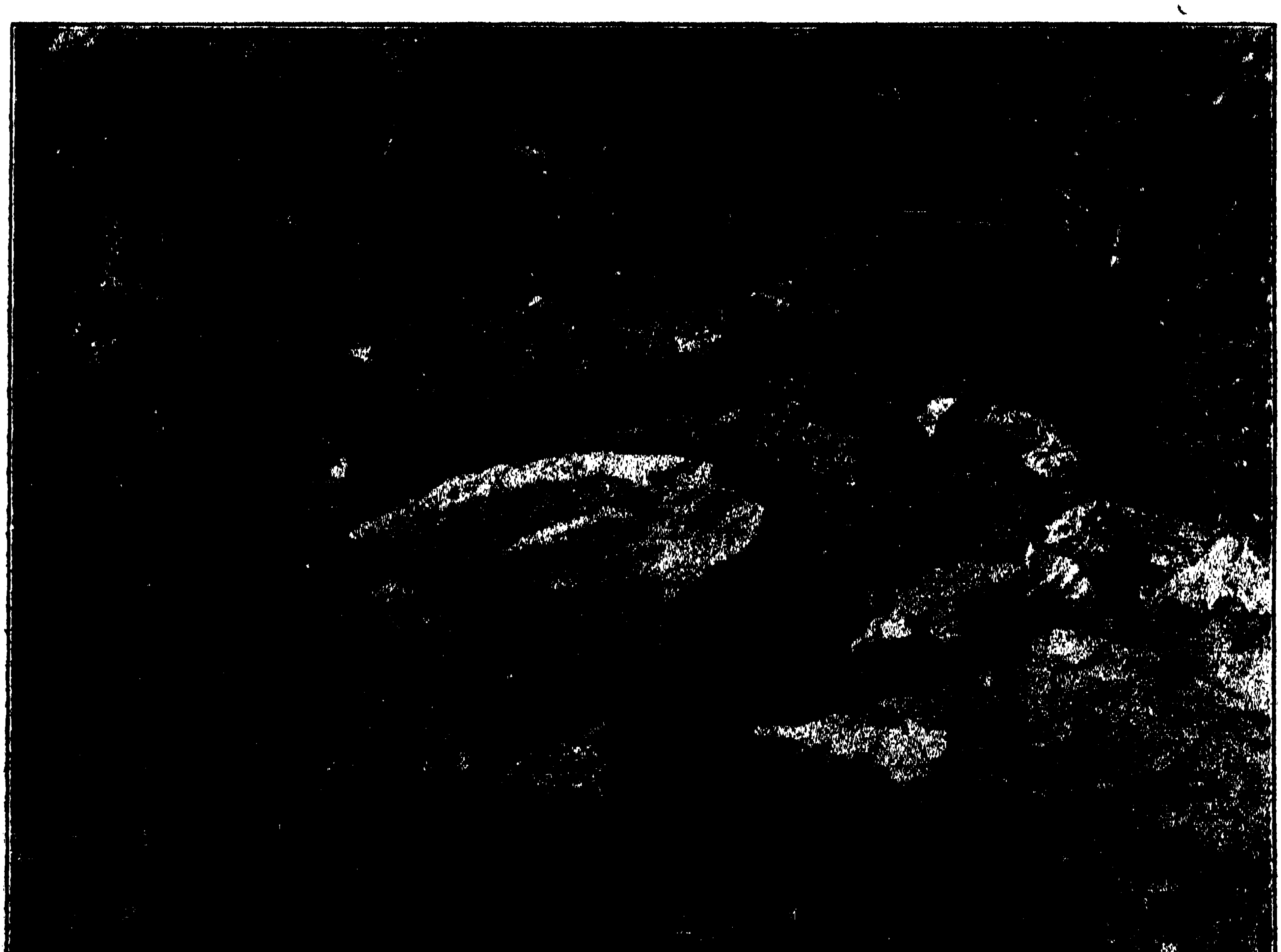


PHOTO SHOWING ROCK BLOCK

Weighing between one and two tons, moved a distance of four inches by a lightning stroke.

steam, and the expanding steam would seem to account for the exploded appearance already mentioned. The tree first struck, dried at the top by the suns of many summers, would naturally show greater explosive effect at the bottom, where it was partly shaded by the underbrush; the moisture at the bottom of the soil, leading the current downhill, would generate a steam pressure upward, apparently quite adequate to lift forcibly a foot or two of soil and produce furrows; the expansion of moisture in the preexisting cracks would move the ton block easily enough; the steam generated beneath the sod would blow back the sod-carpet as surely as steam blew off the lid of James Watt's kettle when the spout was plugged; the moisture in surficial cracks would blow off the chips and produce the flaked surfaces on the exposed bedrock, and the moisture following the twisted grain of the lower tree would have no difficulty in blowing off the weathered surface when vaporized suddenly.

When this explanation suggested itself, a further search of the hillside indicated that the case described was not unique. Other furrows, somewhat subdued by rainwash and vegetable growth, were found; other trees were found shattered, and other rock blocks moved from place. In none of these, however, were the evidences as fresh as in the case described. It seems improbable that the same line will be followed again by lightning, as other trees, still standing, will probably draw the charges in later summers, but similar conditions may be looked for where the immediate grounding of the lightning charge is difficult. Repeated occurrences of the same sort would be quite effective in helping to break up the rock surface and supply material for a new soil cover for this hillside; locally the geological effects of lightning seem more important than they have hitherto been considered.

The schoolboy, writing a composition, seems to have spoken more truly than he knew when he said "The reason why lightning never strikes twice in the same place is because after the lightning hits it, it is never the same place again."

THE PROGRESS OF SCIENCE

AWARD OF THE NOBEL PRIZES IN CHEMISTRY

THE fruits of research to-day are difficult of award. No longer does the worker retire to cell or laboratory for solitary labor and later emerge with an epoch-making discovery that is all his own. Communication has been facilitated and even workers in remote countries keep closely in touch with one another's problems and progress. It is an age of cooperative effort.

The Nobel chemical awards of 1927 and 1928 are examples which emphasize the difficulty of separating individual effort and recognition from the efforts and merits of others who have toiled in the same field. To some, familiar with the tremendous strides made by American scientists toward the solution of the problem of rickets, its cause and prevention, it came as a surprise when Stockholm announced that the Nobel prize in chemistry for 1928 was awarded to Professor Adolph Windaus, of Göttingen University, for explanation of the nature of the provitamin (ergosterol) which becomes rickets-preventing vitamin D when irradiated with ultra-violet rays.

Some, misunderstanding its basis, even resented it as a reflection on the work of Hess, Steenbock, Howland and others in this country or as ignoring the work of Rosenheim, Webster and Barger in England.

The 1927 award to Professor Heinrich Wieland, of Munich, for his work on bile acids and the origin of cholesterol was recognized as a logical tribute to specific work in a given field, but some have puzzled as to why the accounts linked these two names, Wieland and Windaus, together as having relation to vitamin studies.

In 1919, Mellanby, of England, set forth the hypothesis that the cause of rickets was a deficiency of vitamin A. Between 1919 and 1924 we saw the hypothesis negated. We saw two groups of American scientists initiate and carry out the experiments necessary to postulate and prove the existence of the true rickets-preventing vitamin D. We saw two men, Steenbock and Hess, demonstrate that irradiation of living animals or foodstuffs with the ultra-violet light will create this vitamin in inactive materials. To-day we have irradiated foods to help in our defense against this disease, and lamps to produce the healing rays are multiplying in type and numbers. But the problem of what vitamin D is was still unsolved.

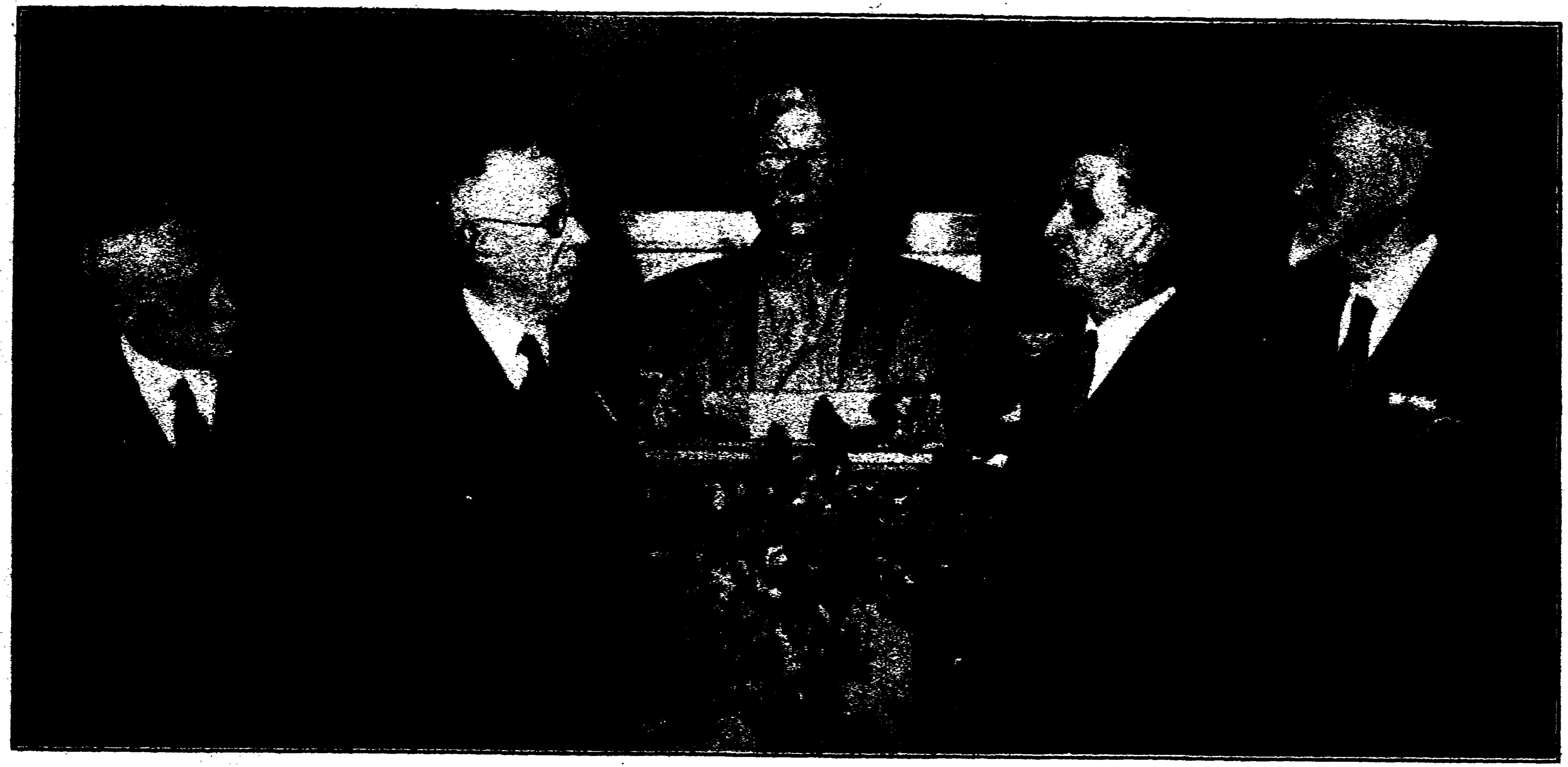
The search went on. Cod-liver oil, its richest natural source, was fractioned. Where the fat was turned to soap the vitamin activity remained in the non-saponifiable fraction. This result narrowed the chase. In 1924 Hess irradiated one of the components of this active fraction (cholesterol) and obtained a rickets cure. It looked like the end of the hunt. Trouble with this simple solution, however, soon developed. Hess's active crude cholesterol was in turn separable into a pure inactive cholesterol and an active residue.

Cholesterol isn't the only sterol. In England Rosenheim ran through a series of other sterols, using the violet ray and test animals. Barger and Webster cooperated, and a sample from ergot developed exceptional activity.

Now we come to Windaus' share in the problem. Twenty-five years or more he had been laboriously studying these sterol compounds. In all the world none knew better than he their character and properties. To him Hess wrote of his perplexities and urged him to turn his knowledge to help with identification.

PROFESSOR ADOLPH WINDAUS
OF THE UNIVERSITY OF GÖTTINGEN

PROFESSOR HEINRICH WIELAND
OF THE UNIVERSITY OF MUNICH



BUST OF PRESIDENT HERBERT HOOVER

Presented by Mr. C. A. Fisher, consulting geologist and engineer, of Denver, to the American Institute of Mining and Metallurgical Engineers at their annual meeting on February 19. Left to right stand Elmer A. Sperry, president of the Sperry Gyroscope Company; Frederick W. Bradley, president of the institute; George Otis Smith, director of the U. S. Geological Survey and past president of the institute, and Dr. George F. Kunz. Mr. Hoover is past president and honorary member of the institute. The bronze bust is the work of Mrs. D. W. Leys, of Yonkers, N. Y., daughter of Mr. Fisher.

To him the English workers brought their ergot product for interpretation. The master in the sterol field demurred at first. He was interested in sterols, not in vitamins. After some time spent in persuasion he turned his experience to the task.

To-day we owe to him definite proof that the ergot sterol is a definite chemical entity, as separate from all other compounds as is salt. We owe to him the suggestions that led to tests on other sterol types and their elimination from potential precursors of vitamin D. His intimate knowledge of sterol chemistry has become a means to further research which may explain what exactly happens to ergosterol when the violet rays impinge.

If we may use a homely analogy, Windaus has been the key man in the team playing in a given contest, the "Poe" of the winning combination. His exaltation casts no dishonor on his team mates, and he has himself been quick to accredit those who consulted him for what they accomplished. May we not then rejoice that the judges had the discrimination, among so many claimants to distinction, to pick this key man as the one signally to honor.

What of Wieland and vitamins? Windaus pursues cholesterol and sterol chemistry. Wieland turns to cholic acid and evolves an explanation of cholesterol formation in the liver. We now know that cholesterol isn't provitamin D, but none knows how soon Wieland's work on cholesterol may provide the key to the metabolism of ergosterol—another example of the value of patient, thorough research.

To workers in other fields the relationships in a given field are often obscured. This tribute to two great chemists is penned to help if possible the understanding of why the Nobel honors are richly deserved.

WALTER HOLLIS EDDY

PRESENTATION OF A PORTRAIT OF DR. GEORGE ELLERY HALE TO THE NATIONAL ACADEMY

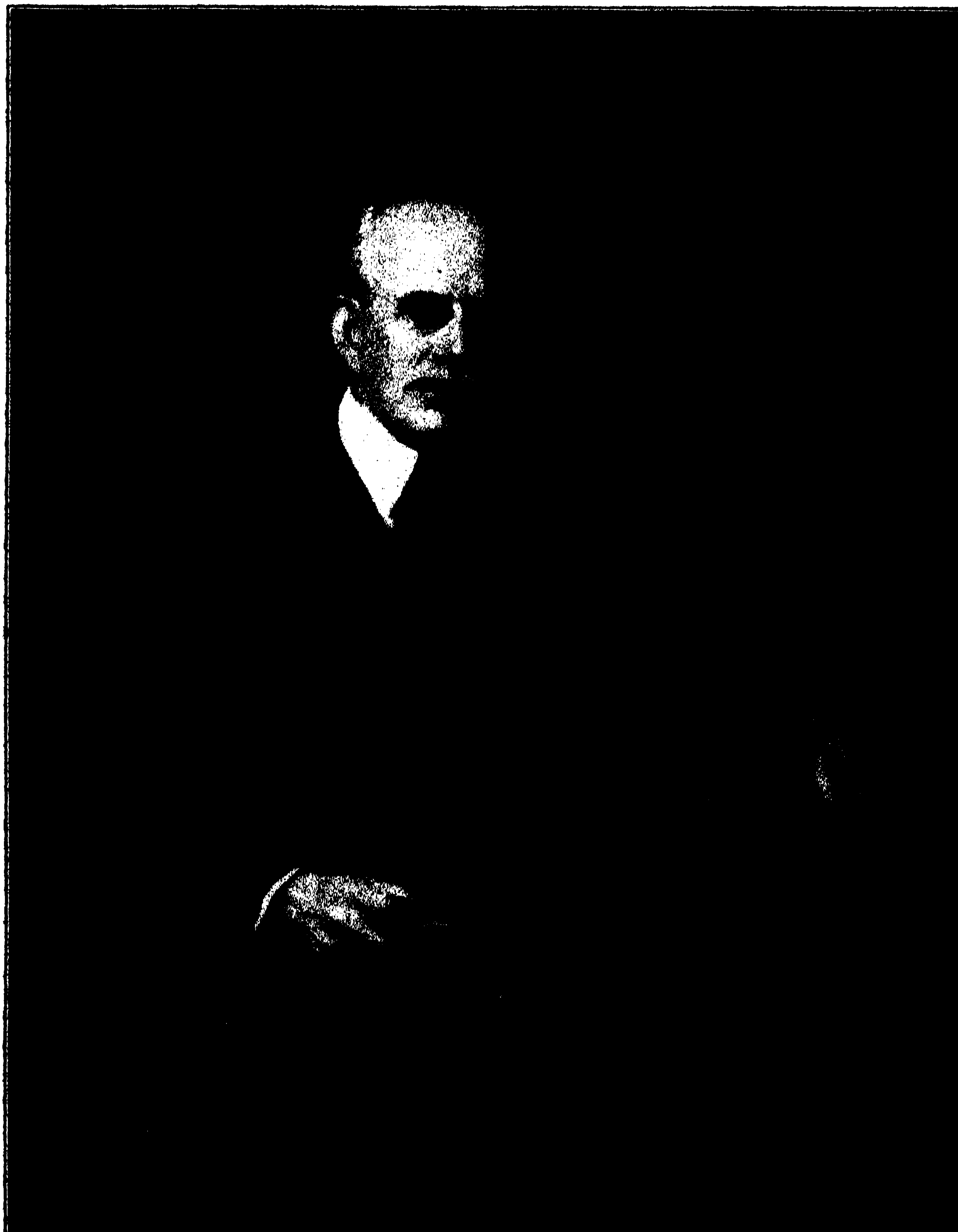
AT the annual meeting of the National Academy of Sciences in 1927 Dr. W. H. Welch presented the following resolution, which was adopted, and Dr. A. A. Noyes was appointed chairman of the committee to take care of the details in the matter of funds and the presentation of the portrait:

Resolved, That the National Academy of Sciences, earnestly desiring to possess a portrait in oils of its fellow member, George Ellery Hale, as a permanent memorial and an adornment of the walls of the fine building which it owes in large measure to his unselfish and untiring efforts in furthering the material and intellectual interests of the academy these many years and whose preeminence in science, universally recognized throughout the scientific world, have added distinguished honor likewise to the academy, requests Doctor Hale to sit for a portrait, to subscribe for which will be counted a pleasure and privilege by members of the academy and by friends and admirers. While the academy must respect limitations imposed by considerations for his health in calling for added services, even if associated with the highest honor in its power to bestow, it rejoices that it may look forward, it is confidently hoped, to many years of useful service restrained only by such consideration: Therefore, be it

Resolved, That the president be authorized to appoint a committee empowered to act upon this request.

In conveying to Doctor Hale this request the academy desires to accompany it with an expression of its grateful appreciation of his services, with felicitations upon a record of signal achievements in science, to which further contributions may be expected, and with its cordial and affectionate greetings and its best wishes for continued and vigorous activity and usefulness.

The report of the academy for the present year states that at the annual meeting Dr. Noyes gave a brief summary



DR. GEORGE ELLERY HALE
FROM THE PAINTING BY SEYMOUR THOMAS.

of how the committee secured the funds for a portrait and how they were particularly fortunate in securing Seymour Thomas, the portrait painter, who was at the time residing in Pasadena, to consent to paint the portrait in Dr. Hale's laboratory. The curtains on the speakers' platform were then drawn aside and the portrait was before the academy for acceptance.

The following communication from Dr. Hale was read:

It is impossible for me to express in adequate language my appreciation of the great and wholly unexpected honor done me by the academy. The resolution presented last year by my old friend Doctor Welch, though far too generous in its terms, touched me deeply. The truth is, of course, that I am only one of many men sincerely devoted to the academy and anxious to see its boundless possibilities fully utilized in the interests of science. I have taken great pleasure in its service and deserve no further reward.

Our national charter, as Elihu Root saw so clearly more than 15 years ago, when he became our close friend and wise counselor, has been the chief source of the academy's progress. Its potentialities have as yet been but partially realized, and I am confident that their further study and utilization will lead to great advances in the future.

Gentlemen of the academy and friends of many years, I thank you most cordially and sincerely, and assure you of my desire to work, to the extreme limit of my capacity, in the service of the academy and the advancement of science and research.

Dr. T. H. Morgan, the president of the academy, then said:

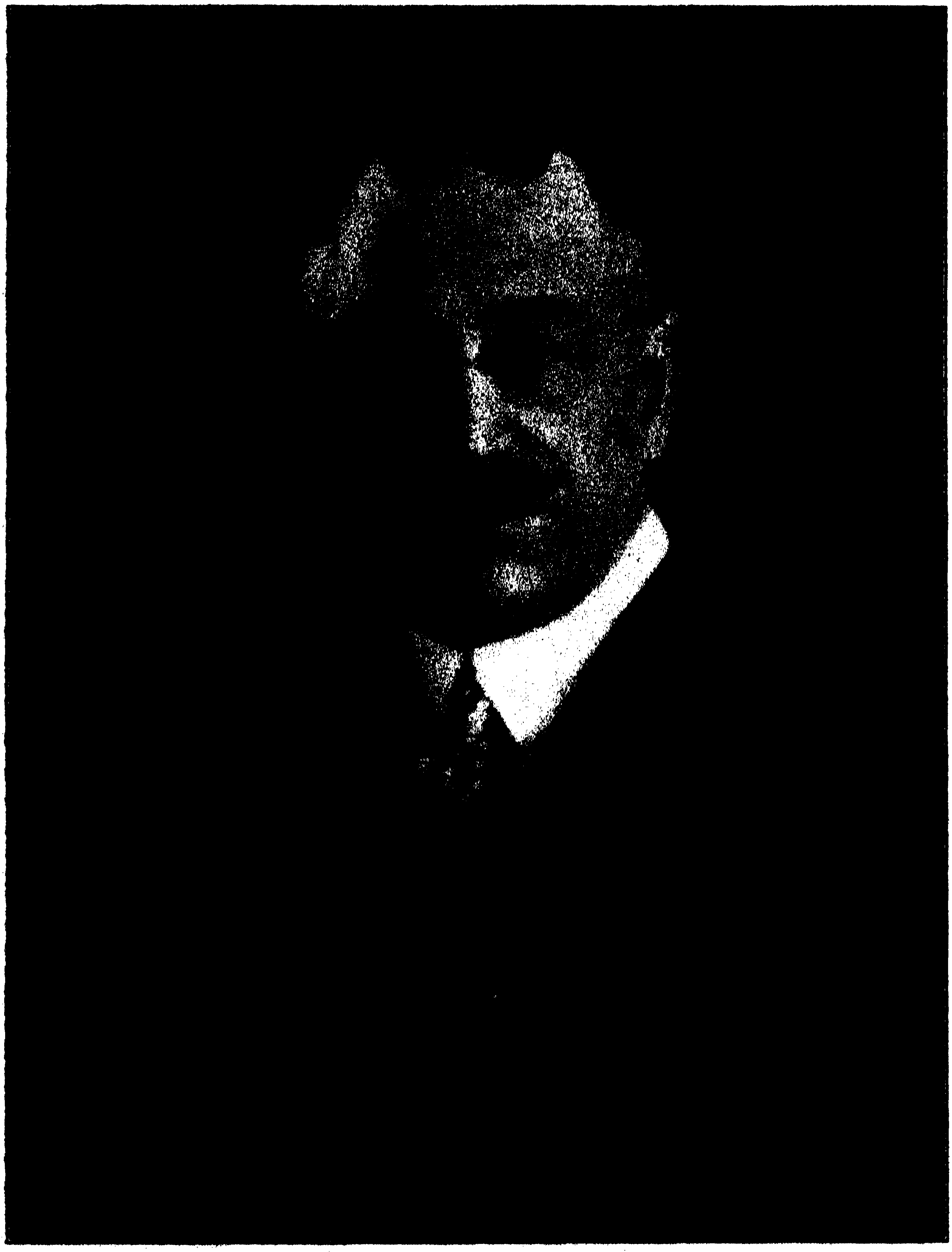
The original motion and its execution call for no further official action unless it be to release the committee and express our obligation to them. Nevertheless, I announce the formal acceptance of the portrait of Doctor Hale as a token of our appreciation of all he has done for the welfare of the academy and of the research council, and of our admiration of him as a great leader of science and of our affection for him as a fellow member.

THE "DANA" EXPEDITION

THE *Dana*, the research vessel of the Danish government, has embarked on a two-year voyage, primarily to study the natural history of the eel. Within the last twenty-three years Denmark has sent out five such expeditions. The itineraries were planned largely with a view to unravelling the habits of this apodal fish which had puzzled specialists in the field of ichthyology.

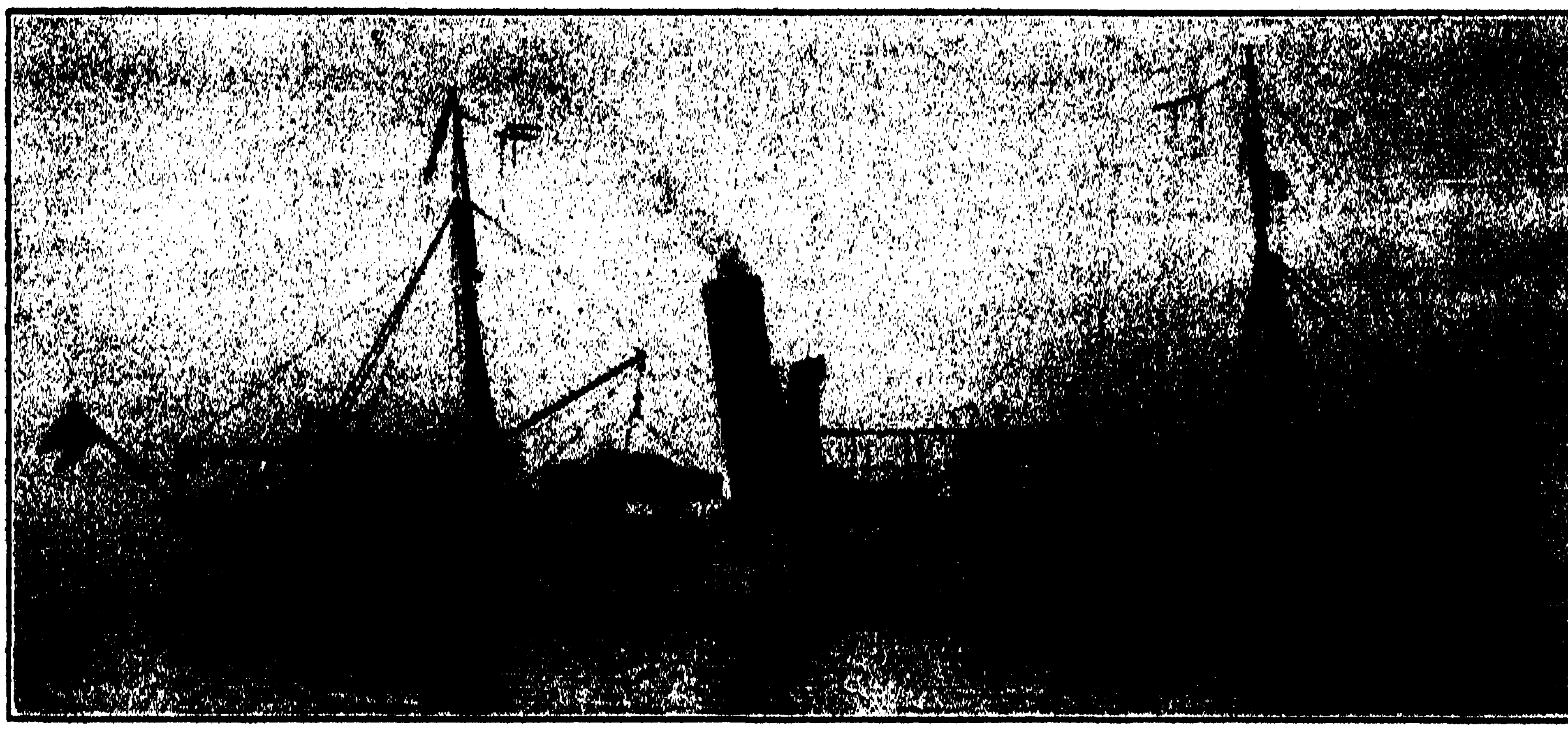
The vessel has been provided by the Danish government, but the costs are defrayed primarily by the Carlsberg Foundation at Copenhagen. Among those on the scientific staff are Drs. Johannes Schmidt, who has long devoted himself to the study of the natural history of the eel, Th. Mortensen, Ove Paulsen and J. N. Nielson.

The projected cruise of the *Dana* is outlined on the accompanying map. The vessel went first to Spain and the Mediterranean; then *via* Madeira to the West Indies and on through the Panama Canal into the Pacific, to Tahiti, the Fiji Islands and New Caledonia; thence to New Zealand and Eastern Australia. Two months were spent in the waters east of Australia, and the vessel is now proceeding northward to Japan and China. Later the Malay Archipelago will be visited (Dutch Indies, Siam, etc.), and investigations will then be made in the Indian Ocean along a line from Java to Madagascar. From Madagascar the course will lie along the East Coast of Africa, and through the Red Sea and the Mediterranean. The expedition is expected to terminate in the spring of 1930. The *Dana* is equipped with the most modern apparatus for the various forms of deep-sea fishery investigations, together with the most recent instruments for hydrographical observations. Throughout the voyage soundings will be taken with an echo-sound-



ALEXANDER A. MAXIMOW

FORMERLY PROFESSOR AT ST. PETERSBURG AND FROM 1922 UNTIL HIS DEATH PROFESSOR OF ANATOMY AT THE UNIVERSITY OF CHICAGO.

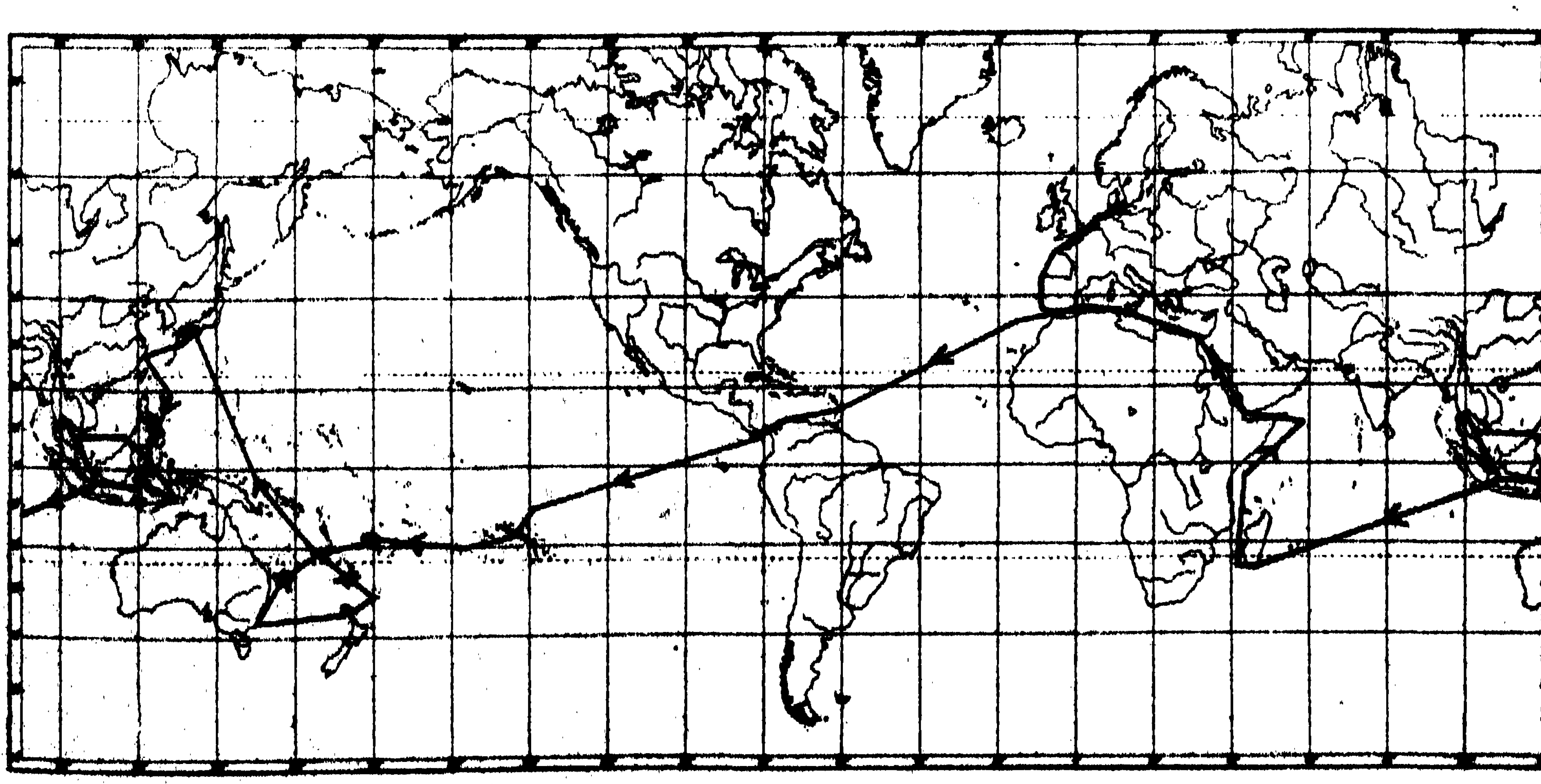


THE GOVERNMENT RESEARCH SHIP OF DENMARK

ing machine. The vessel is in constant direct communication with Copenhagen by means of a short-wave transmitter.

Eels are found in almost all the fresh waters of the temperate and tropical zones, but they do not breed in fresh water. Eggs and larvae have only been found in sea waters, and the fact has now been established that the young eels make their way up from the sea into the rivers and lakes. Here they live until they descend the stream into the ocean, where they spawn and die.

Before the Danish expedition of 1905–06 it was commonly believed that the breeding grounds of the eel were in the Mediterranean, but at that time extensive evidence was gathered to prove that the eels of both Scandinavia and Western Europe came from the Atlantic. Later it was discovered that the eels made their way through the Straits of Gibraltar and that they did not breed in the Mediterranean. Then the interesting observation was made that the eel larvae became more numerous and were smaller



THE ROUTE OF THE *DANA*

in size as one moved eastward across the Atlantic, which was evidence that the breeding of the eels took place in the western part of the ocean.

Then the striking discovery was made that all the eels of Europe spawn only in a small, restricted area of the western Atlantic in the vicinity of the West Indies. The larvae migrate across the ocean and about three years after hatching they make their way into the fresh waters of Europe and Northern Africa. The breeding ground of the American eel was found to be in approximately the same location. These larvae take only one year instead of three to reach the "elver" stage and begin their ascent into the fresh water rivers and lakes of North America. The chief distinguishing feature between the larvae of the American and the European eel is that the former has about eight less vertebrae in its backbone.

A few years ago certain Danish investigators working in conjunction with the International Council for the Investigation of the Sea tagged eels to ascertain the number of miles covered during the migratory period. The records of recapture are most interesting. The rate of migration was found to be about ten miles a day. One particular eel covered a distance of seven hundred and fifty miles in ninety-three days.

THE SCIENTIFIC MONTHLY

MAY, 1929

ISOSTASY AND GEOLOGICAL THOUGHT

By Dr. WILLIAM BOWIE

CHIEF, DIVISION OF GEODESY, U. S. COAST AND GEODETIC SURVEY

EVERY normal human being is interested in the past history of the planet on which we live and is anxious to know what is likely to take place in or on it in the years to come. We are very much handicapped in studying the history of the earth because the processes which are involved in surface changes and in interior activities are slow in their development. The history of the earth is largely written in the sedimentary rocks which have resulted from the consolidation of sediments deposited in valleys and lakes and close to the coasts of tidal waters. These rocks furnish for our inspection and study the fossil remains of plants and animals.

We know more about the succession of life and its evolution from these fossils than we know of the forces which have tilted, deformed, uplifted and overthrusted the sedimentary rocks in which the fossils are found. We know that forces have been active, for it requires power to lift up high an area that was once at sea level. The plateau of Tibet is more than two miles high, on an average, while the highest peak of the Himalayan Mountains is more than 29,000 feet. These and other uplifted regions are the results of forces acting within the earth itself. Then there are the overthrusts. The geologist tells us that material has been lifted and carried over rocks for a distance of as much as twenty-five miles. The force necessary to overcome the sheering and frictional resistance involved must have been great. By processes of analysis and elimination, we can not find any force outside of the earth itself which could form a mountain or a plateau or bend and twist rocks. We must look within the earth itself.

The interpretation of the history of the rocks that we now see above the water, which, at an earlier time, were below sea level, is made more difficult by reason of the tremendous erosion and shifting of material over the earth's surface which has occurred in the geological past. We see only a fragment here and there and we have, by imagination and by the most logical reasoning that is possible under the circumstances, to try to fill in the missing parts. Then and only then are we able to study effectively the past dynamic history of the globe.

In recent years the studies of the geologist have been placed on a firmer foundation, scientifically speaking, although perhaps his problems may seem to be more complicated, as a result of the observations and investigations of other students of the earth. There are the geodesist whose principal line of activity is the determination of the shape and size of the earth, and the seismologist who is the student of earthquakes. The geodesist has found that the surface of ocean waters and of the waters of sea-level canals, extended in imagination through the continental areas, closely

approximates a spheroid, a mathematical surface. The deviation of this water surface from the spheroid is probably not in excess at any place of 100 meters, approximately 330 feet. The actual earth's surface is, of course, irregular. The deepest part of the oceans that we have found lies just to the eastward of the island of Mindanao, one of the islands of the Philippine group, where a sounding of 35,410 feet was made. The highest elevation above sea-level surface is Mt. Everest, in the Himalayan Mountains, which is approximately 29,141 feet. The difference in elevation of the Mindanao sounding and Mt. Everest is 64,551 feet, or more than twelve miles.

The question may arise as to why the earth is a spheroid. Why does it not have the form of a sphere or a cube? The answer is that the material of the earth is not strong enough to maintain any form other than that of a spheroid. If the earth were compressed into a cubical form and the forces that held it so were suddenly released, there would be a collapse which would bring the earth's surface very close to the spherical form, and this would occur almost instantaneously. The earth has been found to have a rigidity equal to that of steel, but even a steel cube as large as the earth could not withstand the gravitational forces that tend to pull all particles of the mass towards its center. The earth, if it were not rotating, would be very closely a true sphere, but this is impossible with a rotating earth. The radius of the earth at the equator is about thirteen miles longer than half the distance between the north and the south poles. The reason for this is the centrifugal force, due to the earth's rotation. If the earth should rotate twice as fast as it is now doing, this equatorial bulge would be extended and the radius at the equator would be far greater than it is now. On the other hand, if the earth were slowed down in its rotation, the equatorial bulge would tend to settle and the radius at the equator would be lessened.

The seismologists have told us that the earth is solid for at least half of the distance down to the center. Therefore surely seven eighths of the earth is solid, and it is very probable that the other one eighth, which is the ball of comparatively small volume immediately surrounding the earth's center, is also solid. The seismologists tell us that, if the earth were not solid, the elastic waves resulting from earthquake shocks could not travel through the deep parts of the earth. As a matter of fact, they do travel more or less in a true line between widely separated points. An earthquake in Japan will make its occurrence known on the records of the seismograph in San Francisco, for instance. A true line between Tokyo and San Francisco lies 775 miles below the earth's surface at the middle point of that line. The reason that there is some doubt as to the character of the center of the earth is that no earthquake elastic waves have been received at a seismograph station from an earthquake that has occurred exactly on the opposite side of the earth. These elastic waves can not travel through a liquid. They would soon dampen out and disappear. On the other hand the longitudinal or compressional waves can proceed through a liquid as well as through a solid.

The investigators of earth and ocean tides and also of the variation of latitude tell us that the results of their labors indicate very clearly that the earth is rigid throughout or, at least, almost to the center. If the center is liquid, then the rigidity of the remaining part of the earth must be even greater than that of steel.

It will be seen that, as a result of the work of others, the geologists have some accurate data which should assist in their attack on the problem of writing the

geological history of our planet. They know that the earth's water surface deviates only slightly from a mathematical spheroid. They know, from several lines of evidence, that the earth is solid throughout with a rigidity equal to that of steel or, if there is some liquid near the center, the remaining part of the earth has even greater rigidity than steel.

The question may arise as to why we have an earth whose water surface is so nearly a spheroid, which yet has such a tremendously irregular surface. This leads to another line of inquiry which has been conducted rather vigorously by the officials of the U. S. Coast and Geodetic Survey and by others during the past twenty years or more. Some geologists of the last century, in studying the earth problems, were of the opinion that continents were in existence because the material of the earth beneath them is lighter in density than the material under the deepest ocean beds and that, if this were not true, the continents would tend to press down into the earth and push out material under the oceans and, eventually, bring about a uniform elevation of the earth's surface. This, we know and they knew, was not occurring and probably will not occur in the future. There was no way by which the geologist could test these views as to the variable densities of the earth's crust. This was something that had to be tested mathematically, and it is here that the geodesist, who is striving to determine the size and shape of the earth, comes into the picture.

Back in the middle of the last century two English mathematicians and geodesists, G. B. Airy and J. H. Pratt, attempted to determine the shape and size of the earth and the lengths of degrees of latitude from geodetic and astronomic data in India. The geodetic data consisted of determinations of latitudes and longitudes and the measurement of distances across the country by means of measured base lines and triangles whose angles were accurately measured. If one side of a triangle and its angles are known, the lengths of the other sides can be computed. This principle is employed in nation-wide surveys of all countries. These triangulation stations, whose latitudes and longitudes can be computed when the shape and size of the earth are at least approximately known, furnish the framework for various types of surveys and maps. The astronomic data were the latitudes determined by observations on the stars.

Since the earth's water surface is approximately a spheroid, a degree of latitude near the equator would be shorter in linear measure than a degree of latitude which is nearer the pole. Pratt and Airy in working over the India data found such wide divergences between the latitudes, as determined astronomically, and those determined from the triangulation that they were led to believe that they should apply corrections for the attraction of the visible masses above sea level and the deficiency of mass in the Indian Ocean. The necessary computations were made and corrections were applied. Then the astounding fact presented itself that the computed values for the attraction for these great land masses were much larger than necessary to bring the triangulation and astronomic latitudes into accord. Each of the investigators arrived at the conclusion about the same time that apparently the Himalayan Mountains were hollow or that there were hollows in the outer portion of the earth just under the mountains or that the densities of rocks under the mountain and plateau areas must be less than normal. The triangulation and astronomic data could only be brought into accord by the existence of one of those conditions. Pratt and Airy wrote papers setting forth their views on this important mat-

ter. This equilibrium theory of Pratt and Airy was later called isostasy by the late Major C. E. Dutton, of the U. S. Geological Survey. Isostasy is a term derived from the Greek and may be defined as equal standing or equal pressure. According to the isostatic idea, the outer portion of the earth exerts an equal weight for equal areas at some unknown surface below sea level. The views of Pratt and Airy and of Dutton did not, for a number of years, receive much attention by the scientific world.

Even the small number of advocates of the isostatic theory were very much discouraged because they could not see any practicable method of testing it. However, about twenty-five years ago officials of the Coast and Geodetic Survey decided that the isostatic theory would have to be taken into account in the determination of the figure of the earth which they undertook. In this determination were used the latitudes and longitudes determined by observations on the stars and those that were dependent on the measurements of distances across country by triangulation. It was believed that the pull of the mountains on the plumb bob, which would deflect it, would be, to a certain extent, neutralized by the deficiency of material under the mountains if isostasy were true. The effect of the attractions of the mountains and plateaus and other land masses and also the deficiency of matter in tidal waters contiguous to the United States were computed. There were also computed the effects of the deficiency of the density below the continental areas and the excesses below the ocean areas which according to isostasy would offset the positive and negative masses at the earth's surface.

In order that isostasy might be tested, certain assumptions regarding the outer portion of the earth had to be made. The first one was that isostasy is perfect—that is, that each prism of the earth's crust down to a certain unknown depth has exactly the same mass as any other prism of equal cross section. Second, that the compensating deficiency or excess of mass lies directly beneath the topographic feature. Third, that the lower limit of the outer portion of the earth in which these heterogeneous densities occur extends to a uniform depth below sea level. Fourth, that the densities of the earth's material above sea level average 2.67 and that the deficiency in sea water is 1.64. None of these assumptions was thought to be absolutely true but they had to be made in order to carry on the work.

Computations were made of the effect of the compensating deficiency and excess of mass distributed to depths varying from ten miles down to about 160. For a depth of about seventy miles, the triangulation and the corrected astronomic latitudes and longitudes came into the closest agreement. In fact, for that depth the differences were exceedingly small. This was a great victory, for it proved that isostasy is probably true. Later, investigations of isostasy involving the values of gravity were made by officials of the Coast and Geodetic Survey.

The values of gravity on a perfectly smooth-surfaced spheroidal body would increase gradually and according to a definite law from the equator towards the poles. This for the earth has been found to be true only to a limited degree. There are disturbing influences involving the masses of the continents and the deficiency of mass in the oceans and the counterbalancing changes in density in the crust beneath them. Therefore, when we reduce our values of gravity to sea level, without taking into account these other factors, the results are very irregular and do not agree well with the theoretical values. However, when the effects of what may be called the topography and the compensation of the

topography are applied to the observed values of gravity these agree very closely with the theoretical ones. The results of the isostatic investigations involving the values of gravity confirm the results that had been obtained from the use of astronomic and triangulation latitudes and longitudes.

The values of gravity used in the isostatic investigations have now been extended widely over the earth's surface. In addition to the United States, gravity data in Canada, India and several states of Europe have been used in isostatic investigations, and for each region isostasy has been found to be substantially true. For many years there has been much speculation as to why the ocean beds are two or three miles lower, on the average, than the continental surfaces. The isostasist claimed that the depression is due to heavier material in the crust under the ocean areas. The question though was a debatable one until a few years ago when Dr. F. A. Vening Meinesz, a member of the Dutch Geodetic Commission, devised an apparatus with which to determine gravity at sea. In this operation, he used a submarine of the Holland navy which was submerged to a depth of about seventy feet at the time of the observations. At that depth the boat is nearly free from the effect of the oscillations of the ocean surface. Dr. Meinesz has circumnavigated the globe in submarines, making gravity observations *en route*, and during last October and November he used his apparatus on a submarine of the U. S. Navy in the Caribbean Sea, the Gulf of Mexico and the Atlantic Ocean between the eastern end of Cuba and Chesapeake Bay. The values of gravity at sea have enabled investigators to show that isostasy is just as true for the earth's crust under the oceans as it is for land areas. We may now assert that isostasy is an established scientific principle.

In order that isostasy may be true, the material of the outer portion of the earth, called the crust, must have what is called residual rigidity; that is, it resists for long time the stresses which tend to make the surface a perfectly flat and smooth one. Below the crust, however, there must be material that is plastic to long-continued stresses. It is rigid to the tide-producing stresses exerted by the sun and the moon as the earth rotates on its axis but those forces act for only a small period of time for any particular part of the earth. They change phase every few hours. Just what causes the change in the physical condition between the crustal and subcrustal material is not known, but it must be a result of the temperatures and pressures which exist at a depth of approximately sixty miles, the best value obtainable for the lower limit of the crust.

With isostasy proved, we must try to learn what is going on in or on the earth to change the surface configuration. We know that each mountain system occupies an area that was once below sea level and on which sedimentary material to great thicknesses was deposited in shallow water. We know also that the mountain or plateau areas, from which those sediments were derived, have been brought to or below sea level. It would seem that there is no such thing as the "everlasting hills." What is now above sea level will probably, at some time in the distant future, be submerged, and recent sediments placed in areas now at or below sea level will be pushed up as mountains.

As material is eroded from the continental areas and deposited in tidal waters, the crust beneath the latter sinks down under the added load, and areas from which the sediments were derived rise up, but the rising will not be as great as the thickness of the material that has been eroded away. For instance, if a thousand feet of material is eroded away from the Rocky Mountain system, it is probable that the area will be restored in elevation to an extent of only 800 feet. This is because the density of material

beneath the earth's crust which is moved horizontally from the area of weighting to the area of unloading is greater than that of the material at the surface. We do not know what is the density of the subcrustal rock, but it is surely three times that of water, or more. The surface density is 2.6 or 2.7, while the average density of the earth as a whole is 5.5. Therefore the earth increases in density from the surface towards the center.

In searching for the causes of the changes in the earth's surface which do not do violence to the principle of isostasy, we are led to believe that the most effective agency is erosion of material from the land areas and the deposition of this eroded material in tidal waters. There may be, and probably are, other factors, but this one is adequate to make an enormous amount of disturbance.

The geologists and geophysicists estimate that the time elapsed since the beginning of sedimentation on the earth is about a billion and a half years. It was at the beginning of that time that water began to fall to the earth and to run in streams and rivers to the low places.

The amount of rainfall now is approximately thirty inches per annum for the land areas of the earth. If this rate should have been maintained during the whole sedimentary age, we should have had about three fourths of a million miles of rain. Of course, there is not that much water on the earth, but this is not necessary. The heat of the sun evaporates the water of the ocean and the saturated atmosphere drops its burden over the land areas and the water again goes to the sea. If the earth were uniformly covered with the waters of the ocean, the depth would be approximately 9,000 feet, or nearly two miles. The amount of rain that we have had is enormously greater than this, so we must have used the ocean waters over many times during the sedimentary age. The evaporation and precipitation and the runoff form a continuous process and will go on as long as the earth receives heat from the sun.

The amount of erosion from land areas is very great in the aggregate. The officials of the U. S. Geological Survey estimate that about one foot, on the average, is eroded from the surface of the United States in 9,000 years—that is, the amount of material that is carried by the rivers and streams to tidal waters and there deposited. This rate would mean, if continued, a mile of erosion in approximately forty-five million years. During the sedimentary age, which is a billion and a half years in duration, we could have had approximately thirty miles of material eroded if there had been a supply so vast. All of this means that any given high area is, in a comparatively short geological time, worn away and reduced to sea level. Then, of course, erosion and sedimentation, as we know the process, cease for that particular region and the adjacent tidal waters but, while that particular high area might have been in process of wearing down other areas would be building up new mountains. Geologically, we speak of periods of active mountain building and other periods during which no mountains were formed. I am rather inclined to think that the formation of mountains and their wearing away are not confined to any particular geological period. They are continuous processes and, in fact, just as continuous as are sunshine, evaporation and rainfall.

The question is frequently raised as to how there could be any runoff of the water during the first rainfall. Was not the earth's surface at that time uniform in height? The answer to this seems to be that the earth had as great irregularities at the time that water first began to fall as it now has. In fact, it would seem that there were greater differences in elevation between the uplifted areas and the depressed ones at

that time than now. In any event, we could not have had running water without an irregular surface and we could not have had erosion and sedimentation without running water. We have abundant evidence that erosion was going on at a very rapid rate in the earliest part of our sedimentary age.

Many theories have been advanced to account for the ocean basins and the continents. The only one that appeals to me as being logical and not doing violence to the principle of isostasy was advanced by Osmond Fisher about forty years ago. Darwin had previously shown that the moon is gradually receding from the earth and that at one time in the distant past it was so close that he was led to the idea that it may have been a part of the earth and had become detached from it. Fisher indulged in some speculation in a very interesting book entitled "Physics of the Earth's Crust," and suggested that the moon pulled away from the earth at a time when a solid shell had formed all around the earth. If the moon had left the earth when the latter was a fluid there would have been no irregularities left in its surface. But it is quite conceivable that, if the earth had lost the moon from the area of the Pacific, after the solid shell to the depth of thirty or forty miles had been formed, the lighter material near the surface would have been thrown away, leaving great gaping wounds. These would have been healed by the upswelling of the subcrustal material which, necessarily, would have been denser than the material that was drawn away. Being denser, its surface would not rise to the height of the original material. A denser layer of subcrustal material thinner than the disrupted crust would just balance the portion of the outer solid shell which had remained after the catastrophe involving the moon's formation. The remnants of the crust that were left would be the present continents and oceanic islands. They would have been fragmented by the terrible commotion that would have been caused by the disruption. We can imagine that the crust under North America and South America would have drawn away from that under Europe and Africa, and that Australia and the East Indies would have been dragged away from the area now occupied by the Indian Ocean. All of this is, of course, pure speculation, but it is certainly a simple theory and one that can account for the presence of continental areas which are underlaid by granite, a light material, while the oceans are underlaid by basalt, a heavy material.

The establishment of the principle of isostasy leads us to the conclusion that earthquakes may be a result of the shifting of great masses across the earth's surface as a result of rainfall. The isostatic equilibrium is undoubtedly maintained at all times. This means that the crust of the earth under the sediments must be pushed down. It is formed of brittle material, and under the great loads will be fractured. When the fracture occurs a vibration is set up which may, if the earthquake is large enough, travel all around the earth and also through it. Then the area of erosion which has been made lighter is pushed up by the subcrustal material. There again the crustal material is brittle and when the forces are too great it snaps and sends out its vibrations. Then we have the process of mountain building which takes place in all cases, as far as we know, along margins of inland seas and ocean areas where sedimentation had been heavy. In the process of uplift to form the mountains the earth's crust is ruptured and earthquakes occur. We also have the sinking of the areas which previously were occupied by mountains, and during the process of sinking the earth's crust is again broken and earthquakes result. This building of mountains and the sinking of former moun-

tain areas must be due to the changes in the temperature of and pressure on the crustal matter which lies beneath the areas of sedimentation and erosion.

We therefore have four causes of earthquakes which are quite in accord with the isostatic principle. There may be other causes of earthquakes but we do not see so clearly what they are. It is quite evident that they are caused by erosion and sedimentation, the building of mountains and the sinking of former mountain areas below the sea.

It would seem that volcanoes are, in a way, closely allied to erosion and sedimentation. Volcanoes along mountain areas probably occur in zones of fracture, in what we call fault zones, where also great earthquakes must have occurred. At the time of an earthquake the rocks must have been fractured and fissured to a considerable depth, say ten to 20 miles. Into the vents thus formed, magmatic material must have swelled upward, or if the outer rock were only crushed and fractured the igneous rocks now soft or liquid must have pushed through the fragments to the surface. Of course, the earth's crust is solid throughout, except possibly in small spaces, but with a fracture extending twenty miles below sea level the hot material at that depth with the release of pressure would become plastic or liquid and move upward. In order that the volcanic theories may not do violence to the isostatic principle the cause of the volcanoes must be an expansion of the earth's crust beneath. If this is true, then the volcanic cone formed at the surface of the earth is not an extra mass added to the prism of the crust on which it rests. Of course, the cone is an extra load on the earth's surface, but there must have been no increase, as a result of the formation of the volcano, to the weight exerted by the prism on the subcrustal material.

Isostasy has certainly come to stay, and the geologists of to-day are using the principle more and more in their interpretations of the earth's history and what is to happen in the future. Surely the geologist who runs counter to the isostatic principle is likely to run into grave difficulties.

The earth is not a rigid, strong, unchanging mass. It is yielding to the changes of load at the surface and would change to conform to any shift of its axis or of its rate of rotation. Probably we are better off with a yielding earth than with a very rigid one, for, otherwise, great stresses might accumulate through millions of years and then when the rupturing came the disaster might be tremendous and overwhelming. We shall have changes in the earth's surface, earthquakes and volcanoes as long as we have sunshine and rain. Without sunshine and rain we should not be very much interested in anything else that might occur.

QUALITY IN GRAPES

By Professor FREDERIC T. BIOLETTI
UNIVERSITY OF CALIFORNIA

A FEW years ago when the shipping of wine grapes from California was beginning to tax the facilities of the transcontinental railroads, two of my viticultural students asked me to arbitrate a dispute as to the relative qualities of Alicante Bouschet and Petite Sirah. One student, who was from Sonoma, stated emphatically that the Sirah was of much superior quality, but could defend his opinion only by saying that this was a fact of common knowledge. The other student, who was from the San Joaquin Valley, stated with equal emphasis that the Bouschet was undoubtedly of higher quality, and backed his assertion by the fact that it brought twice the price of the Sirah in the New York market. I had to decide for the man from Sonoma, but with almost as much difficulty in defending my opinion.

DEFINITION

The decision must depend, in fact, on how we define "quality"—what we mean by the term. If we mean that which makes a thing "profitable" apparently the San Joaquin man was right. But this is hardly admissible. A manuscript accepted by the *Saturday Evening Post* may bring a higher price than one accepted by the *Atlantic Monthly,* but this is not a good measure of its relative quality. In general literature, the word has various meanings. Used in the singular—quality—it is commonly given the abstract meaning of excellence or degree of excellence. Used in the plural—qualities—it is commonly a synonym of characters, characteristics or peculiarities. This distinction is not absolute and the sense intended can be inferred only by the context. When used without qualification, it generally refers to desirable characters. If intended in the opposite sense, it is accompanied by a restricting adjective such as "bad" or "undesirable."

In technical and scientific literature, it is necessary for clarity that each special term shall be used in only one sense and defined as precisely as possible. For our purpose, quality may be defined as the sum or resultant of the *intrinsic* characters of the grape which *give satisfaction to the consumer.* This is in accord with the dictionary definition of "degree of excellence," and excludes price. Price may be enhanced by rarity or other extraneous factors. The quality may affect the price, but the price does not change the quality. This definition, however, is not quite complete because the tastes or preferences of consumers vary, and the taste of the same consumer varies with his experience and his physical condition. A more exact definition is: "Those intrinsic characters which please the most experienced and best-instructed normal consumer." Without experience, a consumer might fail to appreciate the quality of the best Camembert cheese, and a consumer who had been brought up on Concord grapes might fail to find any quality in Black Hamburg. Taste is a matter of both idiosyncrasy and habit, and therefore varies with the individual. This does not mean, however, that there is no standard of taste. Individual tastes vary about a mode, and, as experience accumulates, this mode becomes more definite and gradually moves towards a position that represents the standard of taste of an experienced community.

The nearer our grapes approach this standard, when they reach the consumer, the more we can market and the

higher price we can obtain ultimately. We may be able to market Emperor grapes more successfully than Muscat of Alexandria or Rose Damascus in New York because we are able to get them there in better condition. The Muscat and the Rose Damascus may be of higher quality, more attractive in appearance and eating quality when packed, but too delicate to ship well and may have lost all their good qualities when they reach the market. It is the quality of the fruit when it reaches the consumer that is of importance. However high the intrinsic quality of a variety, it is of little value unless the climate, soil and cultivation of the vineyard enable it to produce fruit of this quality, and unless our methods of handling enable us to preserve this quality until it reaches the consumer. We must not only select a good variety, but we must give it the conditions it needs and handle it properly.

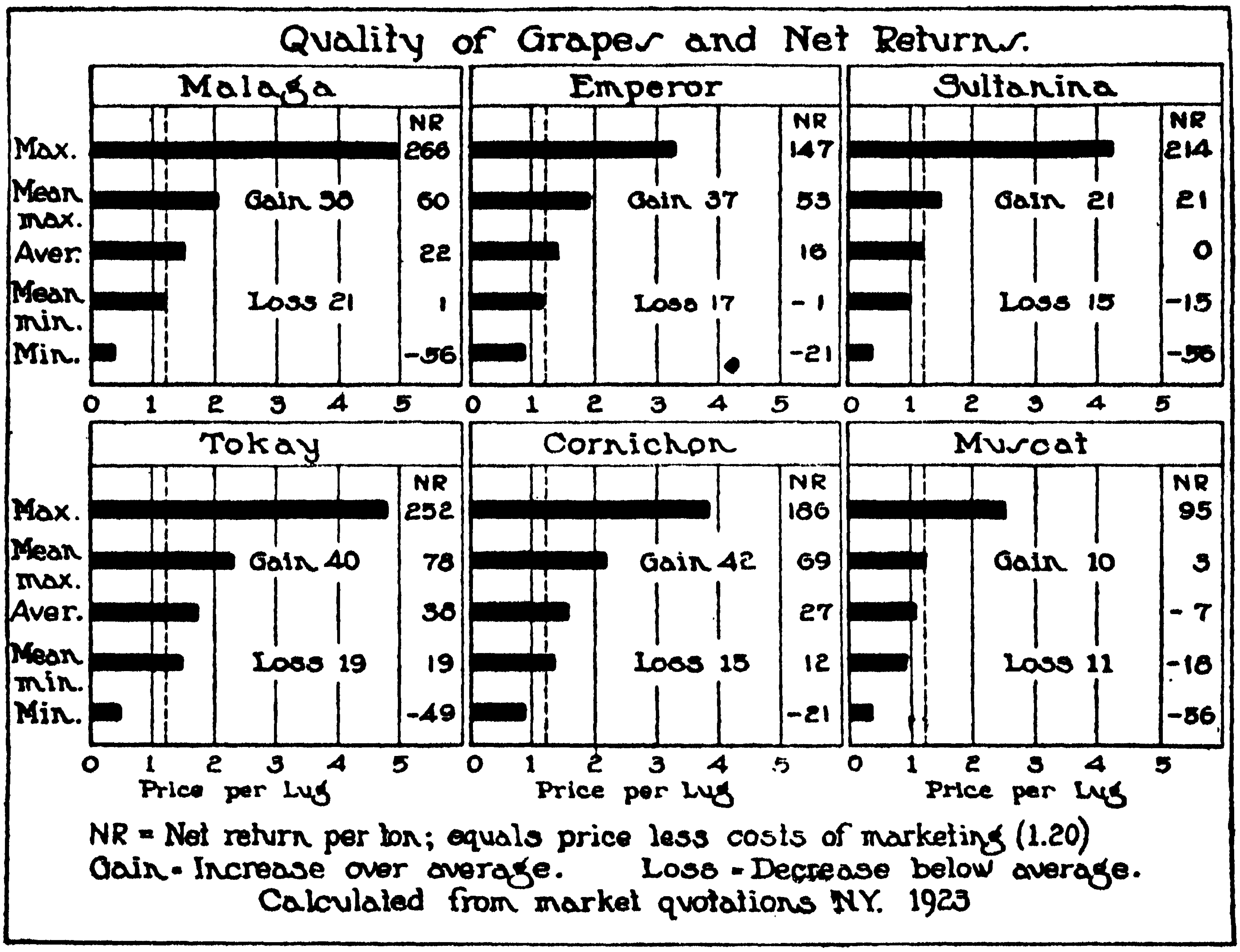
Although the Rose Damascus is extremely brilliant and attractive to the eye and the Muscat richly and delicately flavored, and both more pleasing in all the characters which constitute "quality" when they are harvested, they can not compete with much inferior varieties when they reach a distant market. This is because they lack the keeping and carrying characteristics which enable us to get Emperor grapes to distant markets in as nearly perfect condition as they leave here.

If by improved methods of packing and storing we could preserve the high qualities of our best grapes until they reached the consumer, some of the grapes we now grow would take a lower place in our vineyards, and some of the grapes we grow little and ship less would take a much higher place.

Commercial Value

The variation in price which different varieties owe to their intrinsic quality is less in most cases than the variation due to the condition of different shipments of the same variety. This is shown graphically by the chart. The highest mean daily maximum price for the season was \$2.31 for Tokay, followed by \$2.19 for Cornichon, \$2.05 for Malaga and \$1.95 for Emperor. The average price for these different varieties arranges them in the same order. This variation may be considered to represent principally the relative intrinsic quality of the *varieties* in the opinion of the consumer, and has an extreme range of 100:85. The range between the mean daily maximum and mean daily minimum of the same variety, however, is greater. In Malaga it was 100:74; in Tokay, 100:63; in Emperor, 100:61, and in the Cornichon, 100:41—an average of 100:60. This variation may be considered to represent the variation in *condition* of the various lots as they reached the market. This variation is due (1) to the quality of the grapes when they are harvested and (2) to the degree of skill and care with which they are handled in harvesting, packing and shipping.

The four varieties considered constitute the main crop of Californian table grapes. The other two varieties shown on the table and chart are raisin grapes and only shipped as table grapes in a limited way or occasionally. The Sultanina is shipped, principally and usually, as the earliest grape of the season, while the shipping of Muscat as a table grape is usually confined to comparatively near markets. The average price obtained for these varieties was so low in 1923 that the Sultanina as a whole returned nothing to the growers and the Muscat caused them an average loss of \$7.00 a ton. The cause of this was partly the poor shipping quality of these varieties, especially of the Muscat, but principally oversupply. That under favorable conditions these varieties can



Market quotations of prices of fresh grapes. New York, 1923. (Market News Service. U. S. D. A.)

be shipped to New York with profit is shown by the maximum price of $2.55 a box obtained for Muscat—a price that would return the grower about $95.00 a ton. The maximum price received for Sultanina is even higher, but this represents very early grapes which sold on a bare market. The effect of quality due to condition irrespective of variety is shown by the range between the mean daily maximum and the mean daily minimum. This was 100:65 with the Sultanina and 100:76 with the Muscat. The average variation of price due to condition of grapes which were in good demand was 100:60; of grapes in poor demand, 100:70; and the variations due to the variety of grape only 100:85.

Factors of Quality

We have defined "quality" as that sum or combination of characters in the grape which makes an agreeable impression on the consumer. This does not tell us what these characters are. As they make their impression by their effect on the senses, they can be classified in accordance with these senses. The senses affected are those of sight, taste, smell and touch. These are arranged in the order of time in which they function, not necessarily of their importance.

Appearance. The first impression is made by the sense of sight. If the color, size and form of the grapes are unattractive the prospective buyer loses interest.

Color. Bright colors are attractive. The clear black of the Gros Colman, the brilliant red of the Tokay, the golden yellow of the Sultanina, are particularly attractive. Less distinct colors when united with large size of berry are also pleasing, as, for example, the deep plum

red of the Molinera, and the bronzed greenish yellow of the Malaga. The essential point is that there must be as little variation as possible among the berries of a cluster or package. A mixture of white, pink and red, such as occurs in an ill-colored Tokay, or of green, white and black, in a dense cluster of Black Morocco, is not prepossessing.

The principal use of a brilliant color is to attract the new or uninstructed buyer. If the other qualities are inferior, the buyer soon learns to associate the color with inferiority and the color then becomes a disadvantage. On the other hand, in an experienced market, even a neutral or dull color, such as that of the Traminer or of the Chasselas, may be preferred if it is associated with excellent eating qualities.

Size. Large size, like bright color, always attracts the new buyer. The large black berries and clusters of the Gros Guillaume will sell in competition with the smaller black berries of the Muscat Hamburg to a buyer unacquainted with either of them, but most consumers would reverse their preference after eating a few of each. The case is similar with the large, oval, green Chaouch, and the small, round, green Madeleine Angevine, two extremely early grapes which ripen about the same time.

Form. Unusual form is attractive principally on account of its rarity. There seems to be no other reason that preference is given to the form of the gherkin-shaped Pizzutello and the spindle-shaped Rish Baba over that of the nearly spherical Palomino and Malvasia bianca, except that the latter is the form most commonly occurring in grapes. The attraction of unusual form, however, is real and permanent if it is accompanied by other pleasing qualities.

The impression made on the sight is followed by that made when the grapes are eaten. The grape has a taste, an aroma and a texture.

Flavor. The flavor of a grape, as this word is commonly used, is a combination of the sensations of taste perceived in the mouth with those of smell produced in the nose through the medium of the inner nasal passages. The term "taste" is often used as synonymous with flavor, but it aids in precision to confine this term to those sensations which are perceived only in the mouth and to use the term "aroma" for those sensations which are perceived by means of the organ of smell and which are undetected if a grape is eaten while preventing the passage of air through the nasal passages.

Taste. The taste of a grape consists of the sensations it produces on the tongue and other parts of the mouth as distinct from the aroma, which consists of the sensations produced in the organs of smell through the internal nasal passages. There are supposed to be only four fundamental tastes—sweet, bitter, acid and saline. Variations in taste represent various combinations of these. A bitter or a saline taste is a defect in grapes. The sweetness and acidity affect the quality by their quantity and their ratio.

The sweetness due to sugars and the sourness due to acids neutralize the effect of each other on the palate to a certain extent. A grape with 19° Balling (19 per cent. of sugar) and .5 per cent acid will taste sweeter than another with 22° Balling and 1 per cent. acid. In considering the effect of sugar and acid on quality, this should be kept in mind. In standardization regulations with grapes, only the Balling degree or sugar is considered. This, in most cases, is a sufficient guide, because as the sugar increases to its optimum the acid increases to its optimum. If we find the most favorable sugar content in a well-grown, sound grape, the

sugar:acid ratio will generally also be favorable.

There are some difficulties here caused by variation due to variety and to locality. In the cooler regions, the sugar: acid ratio increases more slowly than it does in the warmer regions. The result is that the grapes have attained their required degree of color, flavor and other factors of quality while the sugar is comparatively low and the acid comparatively high, with a corresponding low sugar: acid ratio. In the warmer regions, on the contrary, the sugar: acid ratio increases more rapidly than the color, flavor, etc., and in order that the grapes shall have their optimum quality, they must contain more sugar and be harvested at a higher sugar: acid ratio.

There is the same contrast between varieties. A Tokay may require 22° Balling and a sugar: acid ratio of 44 to be very attractive, while the Alphonse Lavallée may reach a corresponding stage of maturity at 20° Balling and a sugar: acid ratio of 38.

The sugar: acid ratio alone is unreliable as a measure of quality because the terms can be changed indefinitely without altering the ratio. It is possible that an ill-nourished grape, grown on a weak or much overloaded vine, and a properly developed grape of the highest quality may have the same ratio. The first grape might have 15 per cent. of sugar and .5 per cent. of acidity and the second 24 per cent. of sugar and .8 per cent. of acidity. Each would have a sugar:acid ratio of 30, but one would be inedible, lacking in sugar, acid and flavor, and the other would be of excellent quality in all respects.

Aroma. There is no common word in English to distinguish the sensations due to the sensibility of the organs of smell as affected by the passage of substances or gases from the mouth through the internal nasal orifices. There is, on the other hand, a plethora of terms to designate the sensations arising by way of the external orifices—odor, fragrance, perfume, scent. The word aroma is sometimes used to include both cases, but it is convenient to restrict this term to the sensations due to substances affecting the sense of smell through the inner orifices. Those entering the external orifices can be called odors, but as grapes have little special odor perceived before eating, this is of little importance.

Certain grape aromas are very special. Some such as those of the Muscats, the Malvoisies and the Cabernet, Semillon and Riesling are pleasing. Others such as those of the Zinfandel, Mataro and most Labrusca varieties are less so. All grapes have some aroma, but in most cases of viniferous grapes it is simply what is commonly known as a vinous aroma or flavor, and while differing for different varieties, the differences are subtle and difficult to describe and distinguishable only by a sensitive and experienced palate.

The aroma increases as the grapes ripen and is the principal factor of quality after those of sugar and of sugar:acid ratio are satisfied. The value of allowing most varieties to mature beyond the stage at which the sweetness is sufficient is the increase of aroma. Not only highly aromatic grapes such as Muscat improve in this way but even grapes of milder and more subtle aroma such as Malaga, Tokay and Sultanina.

Touch. The characteristics of texture and structure of pulp, and of thickness and toughness of skin, and perhaps of astringency are perceived by their effect on the sense of touch. Grapes just before they ripen are firm and tough or crisp. As they ripen, they develop various textures. The pulp of some becomes more and more liquid (Pinot and Burger) until the berry resembles a bag of liquid. Others remain crisp (Palomino, Tokay), but quickly break up and

release their juice when eaten. Others remain firm (Perruno, Chauché), and require more masticating to be disposed of. Others retain some of their firmness but become somewhat gelatinous (Muscat, Alphonse Lavallée). Others become soft and more or less juicy (Rish Baba); a few become soft but not juicy, almost mealy (Zabalkanski). The Labrusca varieties (Concord, Pierce) develop in a different way. The central portion of the berry around the seed remains firm and relatively sour, and the skin and adhering layers of the pulp retain the same characters in a minor degree, while the larger layer between becomes juicy and sweet.

Most of the wine grapes are juicy. This is doubtless because no attention has been given to texture in the selection of these grapes, and they have retained this character of the wild *V. vinifera*. Most table grapes, on the other hand, are more or less pulpy or firm because this is a valuable property for handling and keeping and is more agreeable in a fruit to be eaten fresh and has therefore been considered in selection.

Production of Quality

When the nature and value of quality are known, the problem is how to obtain it. It depends: first on the variety; second on the environmental conditions such as climate and soil, and how well they are suited to the variety; and third on the methods of culture, including all the arts of the grape-grower.

Ideals. To strive intelligently for the "best quality" we must know in detail the concrete facts on which this term is based for each variety. Of the numerous details which determine quality some are common to all grapes and some are required only for certain varieties or vary for different varieties.

The qualities considered necessary for the highest grade are:

(1) Good condition—freedom from blemishes due to decay, drying or mechanical injury.

(2) Perfection of cluster—moderate size and normal form; well filled but not too compact for easy and proper packing.

(3) Perfection of berry—large size for the variety (this applies even to varieties of normally small size such as Black Corinth and Sultanina); even coloration of each berry and of all berries; color normal for the mature fruit of the variety or, where this differs in different localities, the color preferred by the market—the red of the Emperor grown in Tulare County is preferred to the deep purple which is normal in cooler regions or different soils.

(4) Full maturity as evidenced by sweetness, flavor and texture.

These factors of quality apply to all varieties, but some modification of degree is necessary with some factors for grapes used for different purposes. For dry-wine grapes, less sweetness is desirable than for table grapes. This does not necessarily mean less sugar but a lower sugar: acid ratio. For raisins, on the contrary, the highest possible degree of sugar and a high sugar: acid ratio is best.

To obtain the highest quality requires somewhat different methods with different varieties, but it is possible to give the general conditions needed in all cases and to indicate the necessary modifications in special cases.

First, we must have a variety suitable to our purpose and to our market. No method of culture can make a good table or raisin grape out of a Zinfandel, and no method can produce an Emperor fit for wine-making.

We must then have a locality suitable for the variety and the purpose. The Ohanez will not ripen in cool Sonoma County and the Chasselas doré will be small and unproductive and lose most of its delicacy in hot Kern County. The soil must be suited to the variety, though this is not usually so important and it can be ameliorated more easily than the climate.

When we have a suitable variety, growing on a suitable soil, in a suitable climate, our success in producing full crops of grapes of high quality depends on our cultural methods. To describe all these cultural methods would require a treatise on viticulture. I will, therefore, point out only some of the special methods of culture which tend to increase the quality of the grapes.

Training, Pruning and Thinning. These operations must be discussed together as one can not be carried out properly except with reference to the others.

The best grapes are produced on well-nourished, vigorous vines which have ripened their wood and buds perfectly the preceding autumn. They will be best only if each vine and each branch bear no greater weight of grapes than they can bring to perfect maturity. Long pruning tends to strengthen the vine by increasing the area of foliage and the time during which it is active. At the same time it tends to the production of excessive crops which are beyond the capacity of the vine to bring to perfection. The net result is often to weaken the vine and decrease its capacity for the following year.

Both of these defects can be avoided by long pruning followed by sufficient and timely thinning, *i.e.*, removal of excessive blossom clusters from the vine or of excessive berries from the cluster while they are very small.

Distribution of the Clusters. A vineyard may not have a very large crop, yet most of the grapes may be on the average inferior because a large number of the vines overbear and hence produce poor grapes, while others produce little or none. The same may occur with individual vines. One arm of the vine may be so loaded that the grapes are small and fail to ripen, while the rest of the vine may have very few.

This defect is avoided by "differential pruning," or better still, by differential thinning. If the weaker vines are pruned shorter they will produce fewer grapes, but grapes of better quality, and the vines will gain in vigor for the following year. If the stronger vines are pruned longer they will produce more grapes, and if too much wood is not left, the grapes will be of good quality and not sufficient in volume to weaken the vine.

As the amount of wood we leave on a vine has a direct ratio to the subsequent growth and vigor of the vine, and as the amount of crop has an inverse ratio, our best plan, where it is practicable, is to leave a generous amount of wood on all vines—strong and weak—when we prune them, and then to limit the crop in the spring by cluster thinning, and, where necessary, by berry thinning, to bring the amount of crop within the capacity of each vine and of each part of each vine.

Clearing the Clusters. A vine may produce many clusters of fine grapes and yet many of them can not be harvested without being seriously injured because they have grown around shoots or interlocked with each other. A fine cluster can be gathered, packed and shipped in perfect condition only if it hangs and develops free from all entanglements.

This is accomplished in the first place by training and pruning the vine so that it spreads sufficiently to allow each cluster full room to grow without touching another. "Head suckering" is used for removing the shoots which might grow through the clusters, but this practice is generally inadvisable because it has a depressing effect on the vines like all pruning, especially the removal of actively growing parts. A better plan is to go over the vineyard when the clusters are formed and the berries about one third grown and clear each

cluster from other clusters and from shoots with which it is entangled. This is easy at this stage and can be done without injury to the grapes. If not done at this time, it must be done at harvesting, when it is more difficult, requires more time and seriously injures or spoils the fruit.

Ringing. This operation, called also "girdling" and "cincturing" and "annular incision," consists in the removal of a ring of bark about one eighth of an inch wide (.1 in. to .15 in.) from the trunk near the surface of the soil or from an arm or a cane below the fruit which it is intended to affect. The smaller the part operated on, the narrower the ring. The effect is to cause the carbohydrates elaborated in the leaves to accumulate in the parts above the wound, including the clusters of blossoms and fruit. The result is that the berries grow larger and usually ripen earlier. If done before blossoming, it promotes setting and thus increases the number of berries. In some cases the increased setting may so increase the number of berries and weight of cluster that the fruit is neither larger nor earlier. In such a case the girdling should be followed by berry thinning.

Girdling is a form of summer pruning and is weakening, in some cases greatly so. Only very vigorous vines can withstand its yearly repetition. It is of much less general application than the other methods mentioned, and in general should not be resorted to until as much improvement as possible has been obtained by the other methods.

LAMPREYS AND THEIR WAYS

By SIMON HENRY GAGE

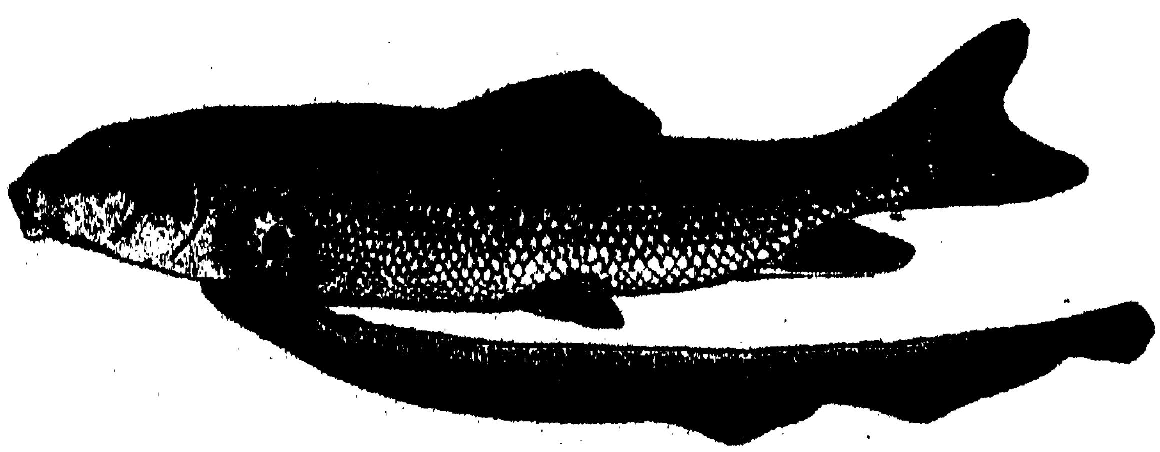
PROFESSOR EMERITUS OF HISTOLOGY AND EMBRYOLOGY, CORNELL UNIVERSITY

THE lampreys,[1] or lamprey eels, are water animals of an elongated, eel-like form. They are usually called fishes, as are most water animals from whales and dolphins to jelly fish. While they are usually described in works on zoology with the fishes, they are not true fishes like the trout, bass, etc., but very much lower in the zoological scale. They have no bones and no paired fins corresponding to the arms and legs of higher forms, and they have no scales. Lampreys do have a dorsal and a good tail fin, and excellent gills. Instead of one gill opening like that in the true fishes, they have seven gills on each side, each with its own opening. The paired fins of fishes and the seven gill openings are shown in Fig. 1; and the gill openings of the lamprey, in most of the accompanying illustrations.

[1]In North America there are at least four genera of the lamprey family (Petromyzonidae): Petromyzon, Ichthyomyzon, Entosphenus and Lampetra. All the members of the genus Petromyzon (sea and lake lampreys) of the Atlantic region, some members of the genus Entosphenus of the Pacific region, and some also of the genus Ichthyomyzon of the Great Lakes and the Mississippi basin, are parasitic in their adult stage. The brook lampreys, spending their whole life in the fresh-water streams of both Atlantic and Pacific regions, are small in size and are not parasitic at any stage. They are represented by the genus Lampetra and by representatives of the genera Ichthyomyzon and Entosphenus.

Lampreys are found in the fresh waters and the oceans of both hemispheres. All begin their life in fresh water, and some remain there always, but others spend a part of their life in the ocean. Wherever they may live, at maturity they all go up into the fresh-water streams in the spring (April, May, June) to lay their eggs. As there are more fresh-water lakes and streams in the larger land area of the northern hemisphere, so there are more lampreys in the northern than in the southern hemisphere.

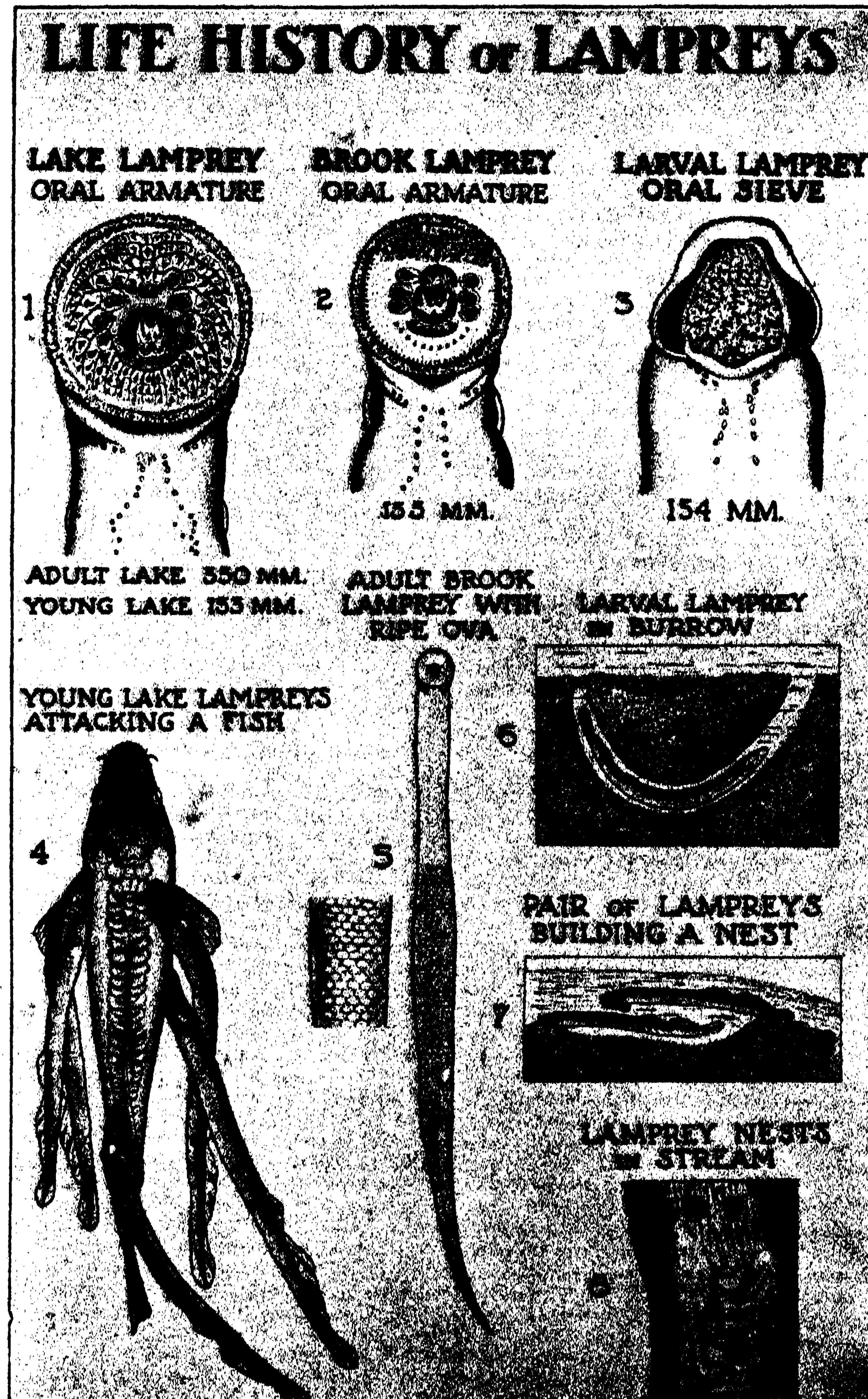
In New England, the large sea lampreys go up many if not all of the rivers to spawn. For example, they are found at the spawning time in the Merrimac, the Connecticut and their tributaries. In New York state the sea lampreys go up the Susquehanna, the Delaware, the Hudson and some of the streams of Long Island. Those that live entirely in fresh water are found in the streams flowing into the Great Lakes, the Finger Lakes and into the Allegheny River. They are also in some of the streams of New England, New Jersey, Maryland, the Mississippi basin, coastal brooks of the Pacific, and many of the streams of the old world.



From Science, September 23, 1927

FIG. 1. LAKE LAMPREY ATTACHED TO A FISH

ABOVE THE PECTORAL AND VENTRAL FINS ARE SCARS SHOWING WHERE OTHER LAMPREYS HAD MADE RAGGED OPENINGS WITH THEIR RASPING TONGUE.



From the N. Y. State Conservation Department

FIG. 2. LIFE HISTORY OF LAMPREYS

All lampreys, wherever found, have two great stages in their life cycle: a young or larval stage, corresponding with the tadpole stage of the frog and the caterpillar stage of butterflies and moths; and an adult stage. The larval stage is always spent in the mud of fresh-water streams. The adult stage of some is passed in fresh-water lakes or streams, while with others a part of the adult life is spent in the ocean.

While the larval lampreys do not look so different from their parents as do caterpillars and tadpoles, yet their mode of life and internal structure is fully as great. The larvae, or ammocoetes as they are sometimes called, live in burrows in the mud and gravel in the more quiet part of the streams not far from the place where they began life as eggs. The water of their burrows contains many microscopic animals and plants, and when the lamprey draws the water into its gill chamber for respiration, the minute animals and plants are carried along. In some way, no one knows just how, a part of the microscopic life is caught or strained out of the water and passed on into the intestine for food. It is this kind of food that they live on during their entire larval life, that is, for four or five years.

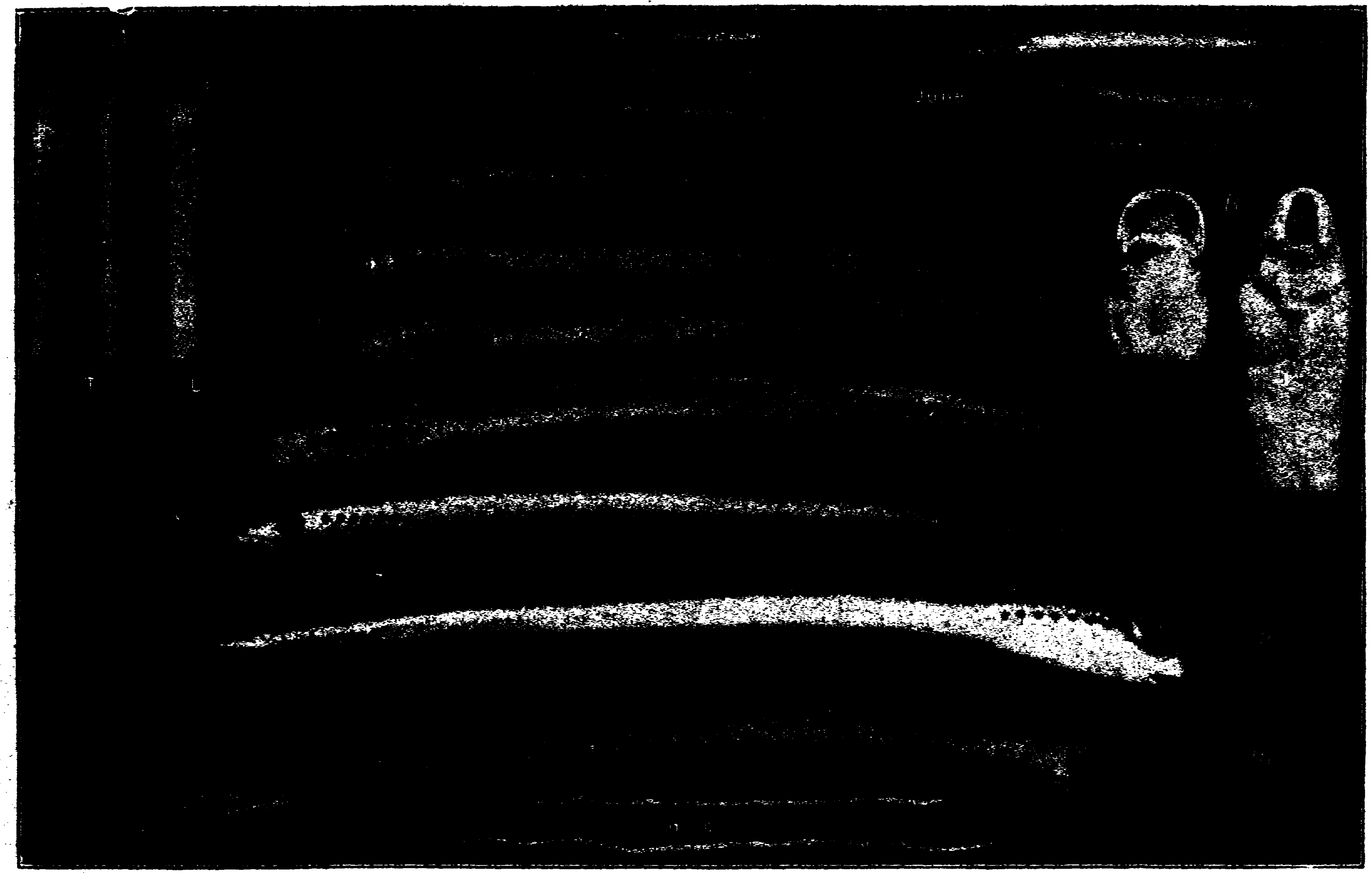
When the streams where they live get roily or turbid from rainstorms or freshets caused by melting snow and ice, muddy water drawn into the gill chamber would be likely to coat the gills with mud, and the coarser particles might fill the gill chamber after a time. To protect itself, the lamprey very long ago devised an excellent strainer in its throat. This strainer is composed of a multitude of finger-like growths from the throat wall which extend all around and cover the entire entrance with a beautiful lace work (Fig. 2: 3). This filter allows the water and the fine particles to pass through, but stops the coarser particles. After a while the strainer is liable to be clogged and thus prevent the water itself from entering the gill chamber. The lamprey learned long ages ago what to do to open the strainer. It closes the seven gill openings on each side of the neck, and then by a powerful contraction of the muscles around the neck, it forces the water back through the strainer, and this reversed stream sends the clogging particles flying.

Sanitary engineers have learned to use this method for cleaning filter beds for drinking water; that is, they reverse the current of water and allow the dirt to flow away with the reversed stream.

To see the larval lamprey clear its strainer, one of the animals is put into a test tube or slender bottle with some water made slightly milky by the addition of starch or flour. The test tube is held in a good light and the head of the animal looked at through a magnifier. A stream of the milky water will be seen passing through the strainer into the gill chamber at every inspiration. A moment later, during expiration, the milky water will be seen coming out of each of the seven gill openings along the side of the neck.

In time the strainer over the throat will become partly clogged with starch masses; then the lamprey will reverse the current and clear the strainer just as it does when the water is muddy.

It was found, when trying these experiments with the respiration, that a part of the starch grains was expelled through the gill openings with the water, but that a part of them was passed on into the intestine, which opens directly into the branchial chamber. This suggested a method of clearing the intestine of sand particles and diatom shells, which are very annoying if one wishes to make serial, microscopic sections. It suggested also that one could feel the lampreys any kind of food for experimental purposes if the food were made



From the N. Y. State Conservation Department, Biological Survey of the Oswego River System (1927)

FIG. 3. LARVAL AND TRANSFORMING LAKE LAMPREYS

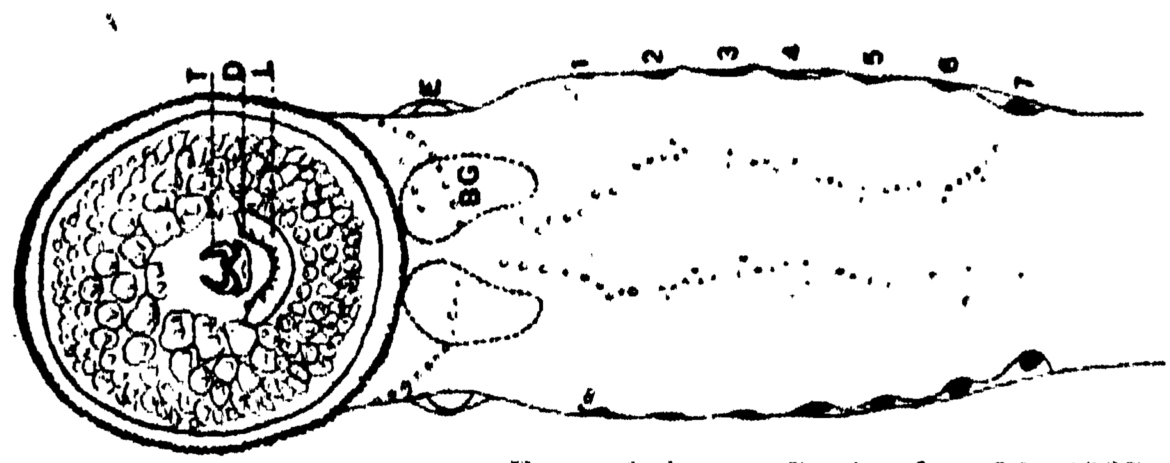
1, 2, 3, GROWTH TO OCTOBER OF THE SAME SEASON. 4, 5, 6, 7, LARVAE POSSIBLY OF DIFFERENT YEARS. 10, LARVA OF UNUSUAL LENGTH, DECEMBER. TRANSFORMATION THE FOLLOWING YEAR. 8, TRANSFORMING LAKE LAMPREY THAT REMAINED IN AN AQUARIUM A WHOLE YEAR IN THE LARVAL STAGE AFTER REACHING FULL LENGTH, TRANSFORMATION APPARENT IN LATE AUGUST. 9, TRANSFORMING LAKE LAMPREY FROM THE MUD-BANK, DECEMBER. JUNE, THREE LARVAE TAKEN FROM THE MUD-BANK SHOWING GROWTH IN ONE YEAR. A, TWO TRANSFORMING LAKE LAMPREYS WITH CONTRACTED CIRCULAR MOUTHS, T, AUGUST. ONE LARVA OF THE SAME LENGTH. L, WITH THE CHARACTERISTIC HOODED MOUTH, UPPER AND LOWER LIP. B, ABOUT TWICE NATURAL SIZE. L, LARVA WITH HOODED MOUTH. T, TRANSFORMING LAMPREY IN A VERY EARLY STAGE, AUGUST. N. C. NOTOCHORDS OF DECAYED LAMPREYS FOUND IN THE STREAM IN JUNE. THE CEPHALIC END POINTS TO THE RIGHT.

fine enough and put into the water. Many kinds of food were tried, and finally some milk was put in the water. Particles of cream and some of the milk got to the intestine. To our amazement the lamprey coagulated the milk just as a kitten or other mammal would. Probably of all the millions of generations of lampreys, this was the first time one of their number had ever had a milk diet, and yet it had a digestive ferment which served the same purpose as the rennin of a mammal (kitten, pig, etc.). As in nature the lamprey never has a milk diet, this ferment or enzyme must be for some digestive process other than the clotting of milk.

The lampreys in the mud do not have good eyes. The eyes are deeply imbedded in the tissues, but when the head is in a strong light, the eyes may be seen as small black spots beneath the skin and other tissues. This does not mean that the little lamprey can not tell when it is light, for if one of them is lying quietly in the bottom of a dish of water in the dark and a flashlight is turned on, it starts as if actually struck and seeks a shaded place. Then, too, there are sensory organs on the body which perceive the slightest movement in the water. This knowledge is very important for their safety. The fish like the little lampreys for food, as the fishermen know full well, and if the lamprey were loafing about on top of the mud in the streams he would be almost sure to be down the throat of a fish if he did not have some means of telling when danger was near. This probably explains in large part why the larval lampreys are so restless when out in the clear water, and why they bury themselves so quickly when uncovered. In their burrows they are comparatively safe, and feel more confidence in the mud than on top of it.

As all forms of lampreys begin their life in the fresh-water streams, and live in the mud for a certain time, a natural query is how long it takes them to grow up sufficiently so that they can transform to the adult stage and swim freely in the water as did their parents. No one knows the answer to that question. Just as the entomologists and every one else who deals with living forms have found, the only way to make sure with any animal is to domesticate it so far as is necessary to control the surroundings, and to watch the changes in any given individual from the egg to the desired stage. No one has ever done this with the lampreys, and therefore the time required for them to grow from the egg to the full larval size of fifteen to twenty centimeters (six to eight inches), has never been found out with certainty. Estimates have been made by collecting the larvae during every month in the year, and judging by the different sizes, or groups of sizes, how many years are represented. Judging from the different sizes obtainable at any given time, authorities have estimated that it requires about four years.

In July and August of 1898, the writer, in seeking to discover all the structural changes taking place in the transforming lamprey, collected many specimens which seemed large enough to transform. These were put into an aquarium with plenty of mud and gravel on the bottom, and with a constant stream of running water. They were dug up every week or ten days to see whether they were changing and how rapidly the change was taking place. Many of them went through the regular transformation changes, but some of the largest ones as well as some of those of medium size did not change at all, but remained in the larval stage. They were kept in the aquarium until the following July and August, and then they changed to adults in the normal way. This demonstrated that, in some cases at least, larvae of full size remain in the mud as



From Science, September 23, 1927

FIG. 4. LAKE LAMPREY

VENTRAL VIEW OF THE HEAD AND BRANCHIAL REGION OF A LAKE LAMPREY TO SHOW THE POSITION OF THE BUCCAL GLANDS AND THE OPENING OF THEIR DUCTS. BG. THE BEAN-SHAPED, BUCCAL GLANDS AT THE LEVEL OF THE EYES (E). T. THE RASPING TONGUE. D. THE DUCT-OPENING OF THE LEFT BUCCAL GLAND. L. THE INFRAORAL LAMINA. 1, 2, 3, 4, 5, 6, 7. THE SEVEN BRANCHIOSPORES OR GILL OPENINGS ON THE LEFT SIDE.

larvae an entire year before commencing to transform. As one can get those of full size from the mud of the streams during any month of the year, it is believed that all live an entire year in the mud after reaching full size before they commence to transform. If this is universally the case, then to the estimated four years as determined by size alone must be added a full year, making five years of life in the mud banks of the streams before transformation.

The transformation is a real one. Structures so characteristic of the larva disappear, and wholly new structures appear. The hooded mouth with an upper and under lip changes by growth into a circular disk with continuous soft edges to make the sucking mouth more perfect for clinging tightly to whatever it is in contact with (Fig. 3: A, B). The lace-like curtain for strainer over the throat disappears, and in place of the soft papillae appear sharp, horny teeth over the disk of the sucking mouth (Fig. 2: 1, 2). The rasping tongue with its savage, rake-like teeth, with powerful muscles for working the rasp, is developed. Where formerly there was a common water chamber for the gills and for the food, the seven gills on each side are enclosed in a separate pouch with an external and an internal opening. A separate tube, the esophagus, connects the throat with the intestine, instead of the intestine opening into the common water chamber for the gills, as in the larva. The eyes appear on the surface and become clear, and their retinal elements are perfected so that the sight is keen. Any one trying to catch them when freely swimming in the water will be convinced that they can see well, and the fish they attack would probably concede that the lamprey has accurate vision.

In the larva there is a gall-bladder with a duct which opens into the intestine, as in most higher forms, but at transformation the gall-bladder and gall-duct disappear so that there is no direct connection of the liver with the intestine. Still the liver grows with the growth of the lamprey. It must therefore have some important function to perform even though its direct connection with the intestine has wholly disappeared. Here is a case where nature has closed the bile duct completely without giving the lamprey jaundice, which emphasizes the fact that the production of bile for digestive purposes is not the sole function of the liver.

Many other structural changes occur, for which considerable time is required. Fortunately, as with tadpoles and caterpillars, the transforming lamprey does not take food during transformation, and therefore is easily kept in an aquarium during the whole process, so that the

time as well as the changes can be determined with exactness. Transformation may begin in the last half of July, during August, or sometimes in September. It requires from four to five months to complete all the changes, and during the time of change the young lampreys live under the mud the same as larvae.

When the organs are so far perfected that the animals can see well, attach firmly with the sucking mouth, and have developed the sharp, horny teeth on the tongue and oral disk, and the digestive canal is ready to do its work, the lampreys come out of the mud into the free water above. Naturally, after fasting from July or August to January or February, that is four to five months, the young lampreys are hungry, and on the lookout for a chance to get a good meal.

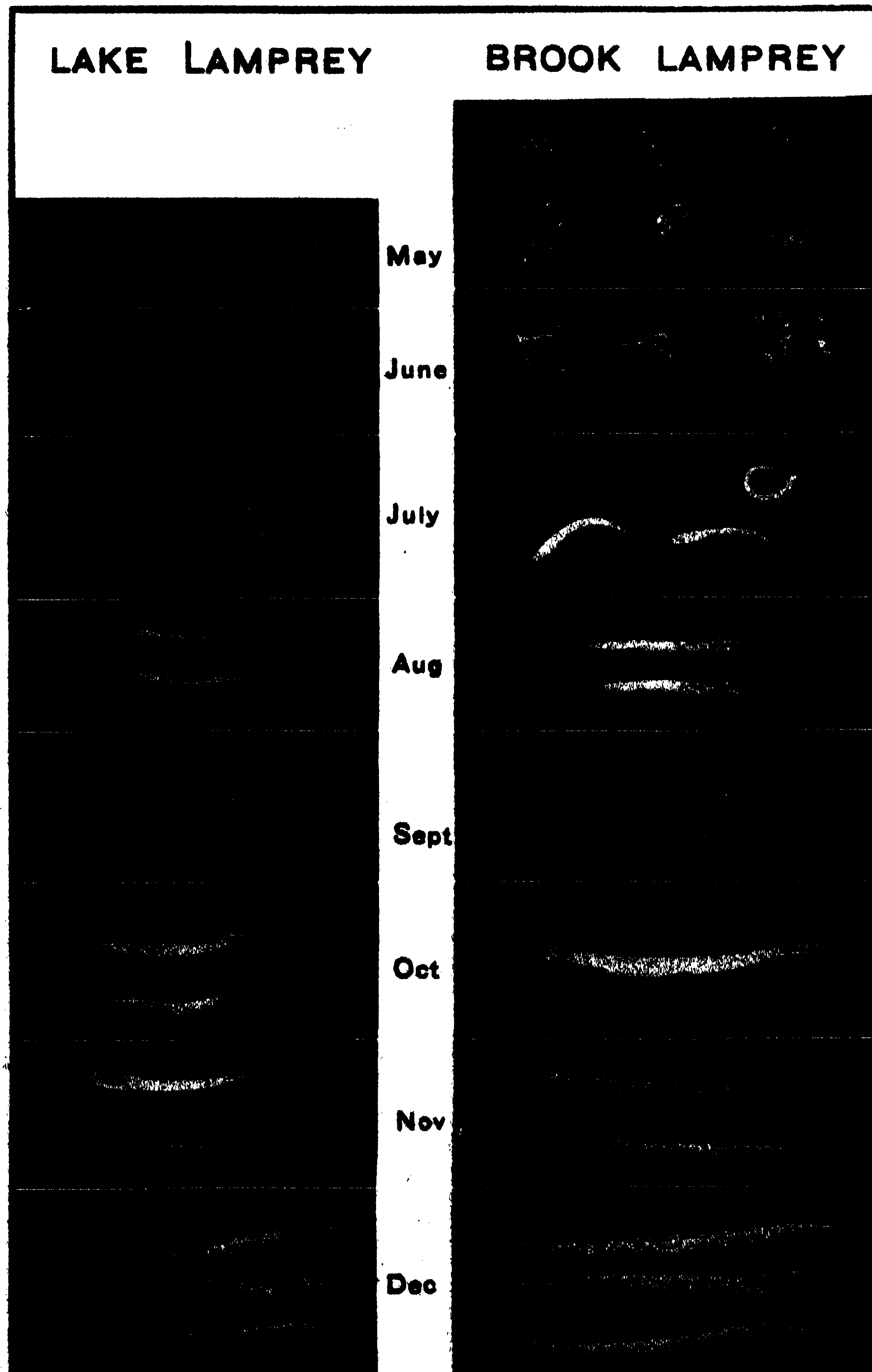
In one experiment, five of the young lampreys were ready at the same time, and they pounced upon the only fish present like a pack of wolves. They clung so tightly to the fish that lampreys and fish were transferred to a small vessel of water and all photographed together under a vertical camera. From the photograph thus obtained was made the drawing for the picture in Fig. 2: 4. Many other experiments were made with the just transformed lampreys, and they always attacked any fish available. Occasionally, if the fish was large and fierce like a pike, it turned the tables and swallowed the young lampreys whole.

In getting a meal the lamprey digs a hole right through the skin and into the muscles of the fish, and in so doing opens many blood vessels. The blood is swallowed and the minced flesh, but the main food is composed of blood. This was proved many times by taking the lamprey from the fish, or by taking lampreys freshly caught in the lake, killing them with chloroform, and then examining the intestinal contents. Much blood was always found in the intestine. That nearest the throat of the lamprey, that is, at the beginning of the intestine, was red, like recently drawn blood, and under the microscope the blood corpuscles of the fish showed perfectly. There was no chance of mistake, for the blood corpuscles of the fish are oval and thicker in the middle than at the edge, while the red corpuscles of the lamprey are circular in outline and are hollowed out in the middle like the red corpuscles of mammals.

Long ages ago when the lamprey first began to steal its food from the body of fishes, it found that the blood of fish clots very quickly when it runs out of the blood vessels and comes in contact with the wounded tissues. This is of great advantage to the fish, for otherwise it might bleed to death from a small wound. It has two real disadvantages for the lampreys: Clots are not so easy to swallow as liquid blood, and the clotting tends to close the torn blood vessels and thus shut off the food supply to the lampreys. To overcome these disadvantages, the lamprey during its transformation developed two glands (Fig. 4) on the underside of its neck near the mouth. These glands produce a secretion which, as the writer found by experiment in 1927, has the power to prevent the clotting of blood.

The glands are surrounded by voluntary muscle fibres which enable the lamprey, when it is digging the hole in the fish, to squeeze the secretion out of the gland through the duct into the mouth. Here it bathes the torn flesh of the fish and mixes with its blood as it comes out of the open blood vessels. The secretion prevents the blood from clotting, and the lamprey can get a good meal of liquid blood.

The vampire bat, the leech and probably many other blood-sucking animals have an anticoagulating secretion to prevent the clotting of the blood of their



From the N. Y. Conservation Dep't. (1927)

FIG. 5. EGGS AND YOUNG OF THE LAKE AND THE BROOK LAMPREY
SHOWING THE GROWTH FROM MONTH TO MONTH DURING THE FIRST SEASON (MAY TO DEC.). NOTE THAT THE BROOK IS CONSTANTLY IN ADVANCE. NEARLY NATURAL SIZE.

victims. No one knows what animal first devised this kind of a gland, but probably the lamprey was one of the first if not the first of all.

In order to find out how often a lamprey needs a meal, how long it remains attached to its victim and whether it always kills the fish it attacks, it was necessary to make some definite experiments. Observations on lampreys in the university aquarium revealed the fact that they are not at all bashful about getting blood from any fish in sight. If very hungry, and no other fish were present, the lamprey would even attack one of the ganoid fishes like the amia or gar pike. Following the hints got from the laboratory aquarium, advantage was taken of the abundance of fish and lampreys in the fall and winter of 1914–15 to make an extended series of experiments to answer the questions which had arisen. One of the bathtubs in the writer's home was turned into an aquarium by putting a good supply of stones of various sizes on the bottom and then adding some fish and several lampreys. To make the surroundings even more like those of Cayuga Lake, some frogs and a necturus were also put in the tub. A stream of water was kept flowing into the tub all the time, thus insuring a plentiful supply of fresh water, and making the conditions as nearly like nature as possible.

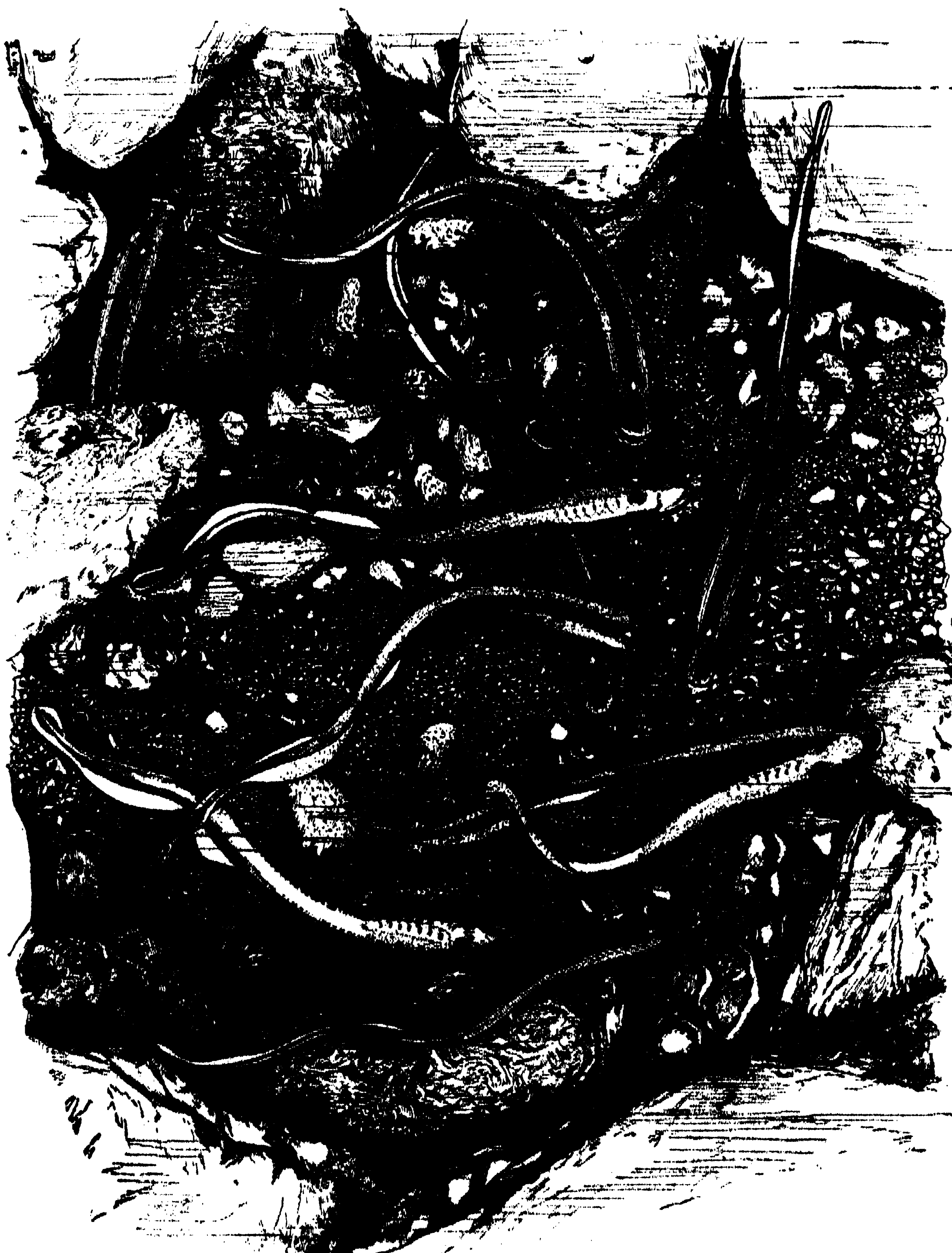
When first brought from the lake, the fish and lampreys were rather restive in the white tub, and tried to get under or behind stones. A part of the tub was covered so that there would be shade or semi-darkness. In the daytime the animals remained mostly in the shade, but at night they swam all about. If a bright light were turned on, they went back into the shaded region.

The lampreys and fish seemed wholly indifferent to one another. Often a lamprey would swim alongside a fish, or when a lamprey was attached to the tub, a fish might swim along and bump into it. This seemed strange, for chickens when they see or hear a hawk, although they were hatched in a incubator, are much agitated, and hurry for cover. Perhaps this is because in the racial history of chickens a hawk in the vicinity practically always meant an attack, while with the lampreys there is only occasionally an attack.

In watching the inhabitants of this bathtub aquarium it was never noticed that the lamprey gave any warning. When hungry it would swim around as usual, and when it got in position by the unsuspecting fish, it would turn, quick as a flash, and, bringing its expanded, sucking mouth up against the fish, stick fast. Then things happened. The fish would dash around the bathtub as if bewitched, and run up the sloping end almost out of the water. But it was of no use; the harder the fish dashed about, the tighter the lamprey stuck, as if the rapid movement had made the vacuum in the mouth even more perfect than at the beginning.

After several minutes the fish seemed exhausted and discouraged and remained quiet. The lamprey seemed to be working away to get something from the fish. The movements of the head and body reminded one of the actions of a pig or a kitten when it is sucking its mother. After some especially hard suck the fish would jump and struggle as if it hurt. Probably it did, for when the lamprey let go or was removed, there was always an ugly hole rasped in the fish (see the black spots by the fins in Fig. 1).

Many attachments were seen. The lamprey could hold fast to almost any part of the fish, but a favorite place is near the paired fins (Fig. 1). Sometimes the attachment was on the head over the eye. In that case the eye was usually dug out by the rasping tongue. This was seen in several instances. If the lamprey did not find a good supply



From the N. Y. Conservation Dep't. (1927)

FIG. 6. BROOK LAMPREY

NEST BUILDING AND SPAWNING OF THE BROOK LAMPREY FROM A DRAWING MADE AT LINCOLN PARK, APRIL 16, 1897, BY BASHFORD DEAN, ABOUT HALF NATURAL SIZE. CUT LOANED BY THE N. Y. ACAD. OF SCIENCES.

of blood in the first hole it dug, it would slide along without letting go and dig a new hole. That explains how it comes about that there are sometimes two ugly holes close together.

If the fish was large enough to supply the lamprey with a full meal of blood and have enough blood left for its own recovery, it would remain alive. However, if the fish was relatively small, so much blood was sucked out of it that it died. This was observed over and over again. That a large fish may survive was demonstrated by the bathtub experiments, and also confirmed by the testimony of fishermen who often find fresh lamprey scars on the fish they catch, and also partly healed scars.

In these experiments the lamprey remained attached to the fish about five days. After leaving the fish the lamprey attached itself to the side of the bathtub or to a stone on the bottom and remained quiet as if it knew the advisability of giving digestion a chance. The amount of blood taken at a meal was estimated by measuring the capacity of the intestine in a full-grown lake lamprey. It was twenty-five cubic centimeters (about one fluid ounce). No wonder the fish looked pale and acted so listless after being drained of such an amount of blood.

The frequency of meals for lampreys was also determined in this series of experiments. A freshly caught lamprey from Cayuga Lake, with its intestine full of blood, was put into the bathtub with various kinds of fish. The lamprey remained content for about a month, then it attacked a bullhead (Amiurus). It remained attached for five days, and then let go of the fish and attached to a stone on the bottom. The same day the lamprey was taken to the laboratory, killed with chloroform and examined. The intestine was full of blood, which under the microscope showed perfectly the blood corpuscles of the bullhead. From this experiment, then, it is concluded that the lamprey requires a full meal of blood about once a month.

The time required for a lake lamprey to attain full size has never been determined. Judging from the different sizes taken in Cayuga Lake at all seasons of the year, it can not be less than about two years, and is more probably three or four years. The lake lamprey (Fig. 3 : 5) increases in length from about fifteen to twenty centimeters (six to eight inches) to a length of thirty-five to fifty centimeters (thirteen to twenty inches), that is, it increases two to three times in length. In weight it increases twenty-five to thirty times. One can get some idea from these figures how much fish blood is required for this growth during the two to four years of life in the waters of the lake. With the large sea lamprey the increase in length is from fifteen to twenty centimeters up to seventy-five to one hundred centimeters, and the increase in weight is about one hundred times. It must take a lot of fish blood for all that growth!

Some years as many as a thousand lake lampreys have been caught in the streams entering Cayuga Lake during a single spawning season, and even a greater number from the streams of Seneca Lake. These figures give a clue to the possible damage to the food fishes of the lakes during the two to four years of the predatory life of the lampreys. Observations upon the fishes caught in the lakes have fully confirmed the supposed damage.

No matter where the lampreys may live in their adult stage, whether it be brook, lake or ocean, when mature, they all go back to the fresh-water streams where they started life, or at least to similar streams, to lay their eggs for a new generation. To get to those places the lampreys may have to swim hundreds of miles and overcome many obstacles; for example, when they pass from the

ocean through Delaware Bay and up the Delaware River to the streams in the Catskill Mountains. Those in the Hudson and the Susquehanna may have to swim as far or even farther, and those in the Pacific Ocean may have to make even a longer journey up the Columbia River and into its headwater tributaries. Those from the Great Lakes and the Finger Lakes do not have to go so far. As can be easily imagined, they are liable to meet many obstacles in these migrations, as do the salmon and other fishes that ascend fresh-water streams to deposit their eggs. All of them show great persistence and often much ingenuity in overcoming the difficulties in the way. From those kept in aquaria in the laboratory during the spawning season (May and June) have come unbelievable feats in their efforts to escape and find the stream they were in search of when caught. To prevent their getting out of the aquarium, overhanging ledges were put all around the edge, but some of them got out even over the ledges. It seemed impossible, but some of them accomplished the feat.

It is told of those going up the Columbia River that they climb the rocks in the steep places by successive leaps, hanging on by their sucking mouths every time in order not to lose any of the progress made. After observing them under many different conditions one can believe almost anything about them.

One very striking, almost human, feature in the sea and the lake lamprey is the brilliant wedding costume they put on as they go up the streams to spawn in May and June. Instead of the modest gray and black of ordinary life, many of them of both sexes become gorgeous in bright orange and black. Sometimes the males are most brilliant and sometimes the females, and often both are equally arrayed, and in the clear waters of the spawning streams they make a very striking and handsome appearance. Not all are dressed up so gaily, for some seem to be satisfied to go in the plainest attire. The coloring is also more brilliant some years than others.

Finally, having overcome all difficulties, and having reached a favorable location where the water is moderately swift and where there is a gravelly bottom, they proceed to make a nest. Often the male precedes the female, and in that case commences the nest alone, but when the female comes along she helps with might and main. The nest is built in this way: From the middle of the place selected, the larger stones are grasped by the sucking mouth, jerked loose, and carried (Fig. 2: 7) or pulled along the bottom down stream some distance and dropped. This goes on for some time until a washbowl-shaped excavation has been made, and there is plenty of fine gravel and sand in the middle of the nest. it would be gratifying to be able to say that when a stone is too big for one of the lampreys the other turns to and helps; but while the writer has watched the building of hundreds of nests, he has never seen two lampreys pulling the same large stone, although if they did pull together, the large stone might easily be moved.

When the nest is far enough along to have an edge of stones and plenty of sand in the middle, the egg laying begins. For this the female attaches herself to a large stone and the male attaches his mouth to the side or top of her head (Fig. 6). Then they curl their tails down to the sand and stir up a great cloud of it. At first it was not easy to see the advantage of stirring up a cloud of sand during the egg laying, but by a little study and observation the reason became clear. As stated above, the eggs are laid in the stream where the water is rather swift, and the current would be liable to carry the tiny eggs down stream if there were not some means of preventing it. The means of

prevention is this: In the ovary a thin layer is put upon the outside of the egg. This covering, becoming very sticky just as soon as it gets into the water, serves to stick the egg to any solid body it comes in contact with. The cloud of sand stirred up by the tails of the lampreys is composed of a multitude of little stones to which the eggs stick and are carried by the heavy stones to the bottom, and thus prevented from going down stream with the current.

If one looks into a nest immediately after a batch of eggs is laid, every egg will be found sticking to a stone. To make sure that the eggs are not exposed to danger of any kind, just as soon as a period of laying is finished, the lampreys commence to pull the stones from the upper part of the nest. This loosens the sand, which is carried down into the nest by the current, and covers the eggs so that, in a short time, none are visible. Safely covered by the sand, the sticky character of the outer coating soon disappears, and the eggs become free among the sand grains and little stones in the middle of the nest.

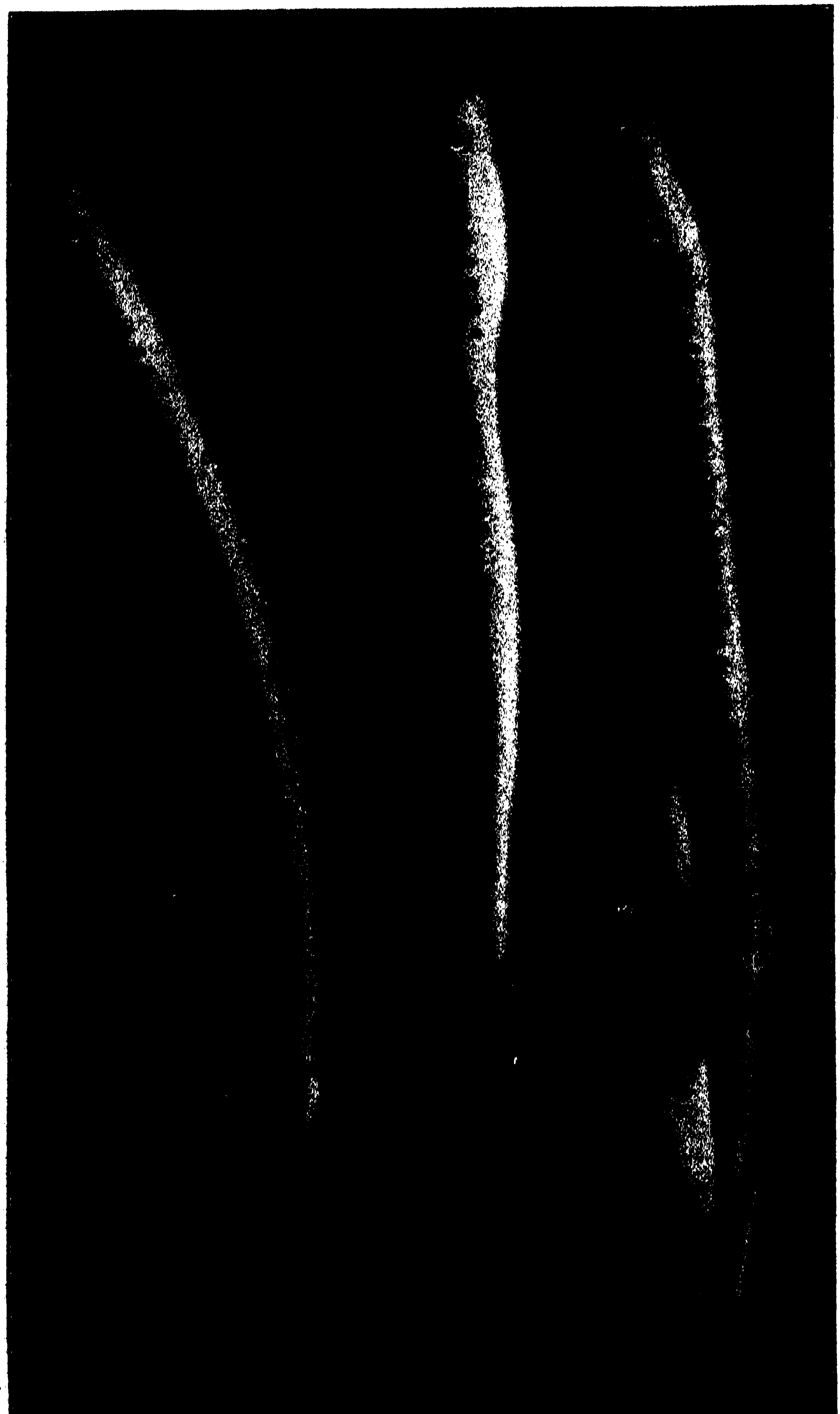
In a few hours the eggs commence to develop, and in a few days, depending on the temperature of the water, the little lampreys hatch and wriggle about among the fine stones in the nest. They stay in the nest until all or nearly all of the food-yolk that their mother put into the egg for them to start life with has been used up. Meantime their heart, blood vessels, a mouth, gills and a digestive tube have developed, and they are ready to take food from the water. It takes about three weeks for all this and many other things to happen. At this time they are about as slender as a pin and about one centimeter long. Their muscles are well developed, and they are quick as a wink, so that it is difficult to catch them.

From the nest they wander in search of a mud-bank in the stream where they will not be so crowded and where there is an abundance of microscopic life in the water to supply them with food.

The parent lampreys, after the egg laying, stay about the nest for a few days, occasionally pulling some of the stones from the upper edge and thus loosening the sand which flows down with the current and covers the eggs still deeper. The life-work of the parents is now complete. The journey, the nest building, egg laying and their long fast have exhausted them, and they soon die. Formerly it was believed by some that they returned to the lake, or to the ocean, if sea lampreys, took food again and recuperated, and got ready for laying another crop of eggs the next year.

We know now that there are no minute eggs in the ovary to grow and produce a second generation, and that the lampreys all die in the streams and never return to the lakes or to the ocean. But as the lake lamprey lays approximately a hundred thousand eggs, and the sea lamprey two hundred and fifty thousand, the continuation of the race is pretty well safeguarded.

As the lampreys have no bones, no bony teeth, and only a few cartilages and some soft tissues for a skeleton, one can see why the remains of the dead lampreys are so seldom found, especially two or three weeks after the spawning season. Curiously enough, however, while there are no bones to persist after the soft parts have decayed, and thus leave a record, there is one part of the lamprey which is quite persistent. It is the notochord, which represents the primitive body axis, vertebral column or backbone. Those first found (Fig. 3: n. c.), were a great puzzle. As shown in the picture, they look like slender worms or snakes. Their origin was determined only by finding decaying lampreys with the notochord partly in place, and then by macerating lampreys in the laboratory. If a paleontologist were to find a fossil notochord what would he call it?



From the N. Y. Conservation Dep't. (1927)

FIG. 7. BROOK LAMPREYS (NATURAL SIZE)

(1) FEMALE WITH EGGS SHOWING THROUGH ABDOMINAL WALL. DARK SPOTS ALONG THE SIDE SHOW WHERE MALE HAD ATTACHED HIS SUCKING MOUTH. (2) MALE SHOWING ELONGATED GENITO-URINARY TUBE. (3) SPENT FEMALE FROM THE SPAWNING GROUNDS IN MAY. SECOND DORSAL FIN SHOWS POSITION OF OEDEMA AND SCARLET SPOT.

Up to 1897–98 the belief was universal that all lampreys were parasitic in their adult life. They all have the sucking mouth and a rasping tongue, and nearly all of them have horny teeth scattered over the oral disk.

In 1897 the author collected many of the large larvae in July and August to get the different steps in the transforming period. Some of the larvae proved to be brook lampreys. As stated above, when the lake lampreys emerged from the mud in January or February, they attacked with great ferocity any fish present. When the brook lampreys emerged from the mud into the free water of the aquarium, they paid no attention to the fish present, but attached themselves to stones in the bottom or to the sides of the aquarium.

Back in 1890–93, the writer found that the brook lampreys in the adult stage were no longer than the largest larvae, and sometimes even smaller. It was found also that the eggs at transformation are nearly as large as when laid a few days or weeks later. On the other hand, the just transformed lake lamprey is only about one third as long as the adult, and the eggs are very minute. It was noticed also that when the just transformed brook lamprey attached to the side of the aquarium and hung down, that the large eggs showed through the thin abdominal wall. Brook lampreys from the streams at the same date showed the eggs through the body wall the same as the one in the aquarium (Fig. 2: 5; Fig. 7: 1). It was concluded, therefore, and abundantly verified during the next ten years, that the brook lamprey of New York State is never parasitic, that its free swimming life is only long enough to find the spawning grounds, build its nest, lay its eggs and then die. It is now believed that this is true of all the small brook lampreys all over America, and indeed in the whole world.

This brings up a profound biological question. All are agreed that parasitism is an acquired habit and not the original mode of life of any form, and as no lamprey is parasitic in its larval stage, the parasitic habit must have been acquired in the adult stage. The sea and the lake lamprey have retained the parasitic habit; but how explain the sucking mouth, rasping tongue and even the anticoagulating glands of the brook lamprey? Without doubt the brook lamprey was also parasitic at one time, but it lost the parasitic habit—reformed, so to speak. Not now being parasitic at any time of its life, it does not need to go to the larger waters of the lake or ocean, but remains during its entire life-cycle in the fresh-water streams where it began life, and where in turn it will lay eggs to continue its race. This is believed to be true of all brook lampreys wherever found.

Some of the brook forms, especially those of the Ichthyomyzon group, have apparently gone further in returning to the non-parasitic condition than most brook lampreys, in that they have lost most, and in some cases apparently all, of the horny teeth both on the rasping tongue and on the oral disk. That is, perhaps they gave up the parasitic habit earlier in geologic time.

In trying to read backward the racial history of the brook lampreys it seems possible, and perhaps probable, that they lived a parasitic life for unnumbered ages. Then for some reason their adult parasitic life became more and more difficult and grew shorter and shorter, until finally—perhaps in the glacial period—parasitism was given up, and the free life in the open water was only long enough to enable them to find a suitable spawning place, build their nests and lay their eggs. At any rate, that is their life history at the present time.

At the end of this story the reader might fairly ask, as scientific men some-

times ask themselves: "What is the good of studying lowly forms like lampreys when there are so many migher forms about which much is yet to be learned?" Those over seventy can well remember the time when men peering into a microscope day after day studying the minute forms of bacteria and protozoa were looked upon with good-natured contempt as having something wrong with their "upper story." And many who are younger can remember how foolish it once seemed to most people that mosquitoes have anything to do with malaria or yellow fever! Now every one knows that the minutest animal and plant forms may exert the greatest possible influence upon human life.

It is not claimed or suggested that the lampreys have so vital a relation to human welfare. They do have some relation, for the large sea lampreys on their way up the rivers and streams to spawn make excellent food for human beings, and the young lampreys from the mud make the best kind of bait for fishing. The adult lampreys of the Great Lakes and of the Finger Lakes of New York are destructive of the food fishes. It is evident that if any wise attempt is to be made to eliminate them, their full life history must be known, and advantage taken of any weak spots in that history. No one would think it practicable to dig up all the larvae in the mud-banks. It would be equally futile to try to catch all the adults scattered throughout the waters of the lakes. But as all the adults go up the streams to spawn at approximately the same time, they become concentrated, so to speak, and then it would be possible to catch and destroy them on their way, thus preventing the eggs from being laid for a new generation.

After all, however, the purely economic advantage to be gained from a knowledge of these lowly animals is not enough to inspire laborious experiments and study throughout long years. The real impelling ground for such investigations is the desire to know for its own sake, and the hope that by the study of simple forms there will come to light some of the underlying principles which determine living structure and action—principles which in the end may help in the understanding of the more complex structures and functions of the higher forms and, finally, of human beings.

Perhaps the thought the author is trying to convey as to the underlying reasons and explanation for the zeal with which investigations are pursued may be clear to many through the medium of poetry:

Flower in the crannied wall,
I pluck you out of the crannies—
Hold you here, root and all, in my hand,
Little flower—but if I could understand
What you are, root and all, and all in all,
I should know what God and man is.
—*Tennyson.*

As with fingers of the blind,
We are groping here to find
What the hieroglyphics mean
Of the Unseen in the seen,
What the thought which underlies
Nature's masking and disguise,
What it is that hides beneath
Blight and bloom, birth and death.
—*Whittier*, in "Agassiz's Prayer."

SOME OF THE SCIENTIFIC PROBLEMS OF TANNING

By Professor GEORGE D. McLAUGHLIN and Dr. JOHN H. HIGHBERGER
RESEARCH LABORATORY OF THE TANNERS' COUNCIL, UNIVERSITY OF CINCINNATI

WITHIN the last two or three decades a fund of knowledge has been growing up, in part transferred and applied from other fields, in part amassed by patient workers within this particular one, which to-day constitutes what we know of the particular sphere of scientific effort which is called "leather chemistry." This, as its name implies, comprises the study of the phenomena occurring during the transformation of animal skin into the non-putrescible material called leather. Probably few people realize that what occurs during this process presents, for the investigation of the leather chemist, a set of problems which are as complex, and, for the most part, as little understood as are to be found anywhere. In order to be impressed with the truth of this statement, the reader need only consider those two great fields of organic chemistry with whose progress the art of leather making is so very closely bound up—the animal proteins and the vegetable tannins, the foundation stones of our knowledge of both of which, curiously enough, were laid by the patient effort of the same great chemist—Emil Fischer. And while the modern leather chemist is sometimes given to understand that the alleged "applied" nature of his work is beneath the dignity of the "pure" scientist, yet consolation is found in the fact that the field of tanning has interested men such as Fischer, to whose name may be added those of Lavoisier, Humphrey Davy, Berzelius, Dumas and Liebig. It is also pertinent to reflect that two of the pioneers in the newer conceptions of the molecular structure of the proteins are the leather chemists, Stiasny and Bergmann, and that the entire work of Jacques Loeb on colloidal behavior—disappointing though it has since proven—was based upon the earlier investigations of the two leather chemists, H. R. Procter and J. A. Wilson.

The laws which underlie the chemistry and physics of living and of dead animal skin are of interest to a widely diversified group. The medical worker attaches importance to the skin's form, structure and function and he is learning that skin disorders are usually symptomatic of still more important disturbances of other organs or of body processes. Those physiological chemists who have considered the subject recognize the usefulness of skin as experimental material because of its close relation to other animal tissues, and rejoice in the fact that excised skin changes in composition less rapidly than do many other excised tissues. The great bulk of the experiments performed in the problem of the hydration and dehydration of tissues and other organic colloidal material have been made with gelatin—a skin derivative.

Animal skin is thus of interest to the scientist if only by reason of its great usefulness as an experimental material in the investigation of colloid chemical problems, but it also possesses a greater and more intrinsic interest in its structure and composition, which we shall describe briefly, and follow by a discussion of that curious and interesting

phenomenon which the tanner terms "unhairing." Although we shall confine our remarks in particular to the skin of the steer, they may be applied in a general way to almost any animal skin.

Histologically, skin may, for the present purpose, be divided into the epidermis, the corium and the fleshy adipose layer which connects the skin to the underlying body. The hair or wool is held in a pocket or follicle which dips down into the skin below the surface epidermis; the depth of the follicle's penetration varies with the type of animal. The inner lining of the follicle which holds the hair is a downward extension of the epidermis. In the upper portion of the skin are found the fat and sweat glands together with elastin fibers, nerves and the erector pili muscles, one of which is attached to each hair. It is the contraction of this muscle which causes the appearance of the phenomenon called "goose flesh." Distributed throughout the entire skin are to be found blood vessels.

The corium—which composes the bulk of the weight and thickness of the skin—is made up of interlacing bundles of collagen fibers. These bundles are bathed in a lubricating and cementing protein (or mixture of proteins) which is of the coagulable type. The corium contains few fat cells or elastin fibers, although it is plentifully supplied with blood vessels.

The adipose layer is composed of tissue, fat cells and muscle, and is well supplied with blood vessels.

When skin is examined chemically, it is found to contain the four great classes of substances which characterize all animal tissues—proteins, fats, carbohydrates and mineral salts. Of these it contains about 35 per cent. protein, 1 per cent. fat, 1 per cent. mineral matter; with only traces of carbohydrates, together with about 60 per cent. water.

The proteins, of course, are the basis of all living tissue, the substances which seem to be most closely concerned (if any one class of substances may be said to be so more than the others) in the chemistry of the vital processes. In the representatives of this family which are found in skin we have an interesting example of the ability of nature to adapt materials to external conditions. The proteins of those tissues where the metabolic rate is highest, and which are protected from external influences, such as the blood, cardiac muscle, etc., are extremely complex and extremely sensitive to changes in physical and chemical conditions. Slight changes in reaction alter them in some way, slight increments of heat coagulate them and change them entirely, and it is very doubtful whether the proteins of this type which the chemist isolates for examination are the same entity in his test-tube that they are in their natural environment. Since the principal function of the skin, however, besides the rôle it plays in respiration and the removal of body wastes, seems to be one of protection to the more delicate tissues, which it serves as a kind of armor, the molecular architecture of its main protein constituents has been altered in such a way as to make them rather resistant materials. The chief proteins of the skin belong to that class which are called by American biochemists "albuminoids," and by their British confrères the "sclero-proteins," that is, the hard, or tough proteins. As to what is the nature of the difference between the skin proteins and other proteins, which gives them their distinctive properties, we are still very much in the dark. With one or two exceptions they are built up of the same amino acids, so that the difference is evidently due to a different arrangement in the molecule of these "building bricks," as the Germans call them. One hypothesis holds that,

instead of the simple open-chain structure which is generally assumed to exist in the ordinary proteins, these albuminoids are built up of the amino acids linked in heterocyclic rings, or double anhydrides. Many of these anhydrides of the simple amino acids have been prepared, and they are found to be extremely insoluble substances, quite resistant to hydrolysis, which lends some support to the idea.

The albuminoids which are found in skin are keratin, collagen and elastin. Keratin is a more or less generic term which probably embraces a number of similar proteins. Thus the proteins of the hair and of the epidermal layer are both called keratin, and yet there is considerable difference between them. The chief chemical characteristic of the keratins, apart from the properties already mentioned, is their relatively high content of the amino acids cystine and tyrosine. Cystine was until very recently the only sulphur-containing acid known to exist in the proteins, and the keratins are thus distinguished by their larger content of sulphur.

Collagen forms the bulk of the protein present in skin, and the corium consists almost entirely of it. It represents about 33 per cent. of the total weight of the skin, and is the material in which the tanner is chiefly interested, since it is the substance which combines with the tanning agents to form leather. The name collagen literally signifies "glue-former," as the protein is changed on boiling with water or dilute acids into glue or gelatin. For this reason it has been suggested that collagen is the anhydride of gelatin, but as to its actual molecular structure we know no more than we do of the other proteins.

Elastin is a peculiar type of protein, which, as its name suggests, is the essential component of elastic tissues. It is present in the skin to only a small amount.

Proteins of the heat coagulable type—albumins and globulins—are also found in the skin to a very small extent. As has been mentioned, their function seems to be that of a lubricating and cementing mixture for the bundles of collagen fibers.

The carbohydrates occur in skin only in traces, and there is some evidence that they are present as compounds similar to glycogen.

The fatty material of the corium, except for a somewhat lower saponification value and the presence of an appreciable quantity of lecithin and cholesterol, has approximately the same characteristics as beef tallow. Only a portion of this fat is in the free state, as is evidenced by the few fat cells to be found in the corium; most of it seems to be in some sort of combination, which may be broken and the fat freed by the action of acids or of proteolytic bacteria.

The mineral matter of skin represents about 1 per cent. of its weight. The principal elements present are sodium, calcium, iron, magnesium, phosphorus and silicon. There are undoubtedly many others present in traces, but these have not yet been determined.

The Unhairing of Skin

All skin which is made into leather (except furs) must first be dehaired. That is, the entire epidermis (including both that on the free surface and that lining the follicle) must be decomposed, enabling the hair and the now disintegrated epidermal material to be mechanically removed, together with the fleshy adipose layer. This epidermal disintegration is accomplished by a process that has been employed for many centuries which consists in soaking the skin in a saturated solution of calcium hydroxid until the desired decomposition of the epidermis has been attained. Any alkali will bring this change about but lime is the most desir-

able, because of its limited solubility and its cheapness. Also, lime dissolves less of the underlying corium than do most other alkalies. It is general practice to use the same lime solution a number of times before discarding it, since it was early found that such a practice caused the lime solution to act more rapidly and effectively upon the epidermis. Curious anomalies arose in the tanner's unhairing practice; no two reused lime solutions acted exactly alike, nor did any two skins exhibit similar behavior—hence the impossibility of operating according to any rule.

For some fifty years leather scientists attempted unsuccessfully to understand the fundamental mechanism of unhairing and to answer the questions: (1) Is the process a purely chemical one, or are the bacteria and enzymes carried into the lime solution by the always partly digested skin necessary for the lime's action? (2) What is the reason for the "mellow" or reused lime solution's behavior towards the skin, compared with fresh or non-mellow lime? (3) How is this mellowness brought about?

Earlier studies failed to solve these problems because investigators were either chemists or bacteriologists, limited by the special knowledge of their special science. The answers were found only when chemists and bacteriologists attacked the problems simultaneously and cooperatively. A brief description of their work follows.

Examination showed that typical skin bacteria were unable to live more than a few hours in the presence of saturated lime; that only spore formers survived and that a very old, mellow lime (through which many lots of skins had passed) contained very few bacteria and even these were not active. And, in addition, it was found that sterile skin was easily unhaired by sterile lime solution. Further experiment proved that the skin enzymes were inactivated by saturated lime in from fifteen to thirty minutes.

With the elimination from the field of both bacterial and enzymatic agencies, it became evident that the liming process was, therefore, of a purely chemical nature. And it was found that the chemical reaction between the skin epidermis and lime may be followed quantitatively by the amount of sulphur dissolved in and by the lime solution. This sulphur is derived from keratin, the protein of the epidermis which, as already mentioned, contains the amino acid cystine ($HOOC \cdot CH(NH_2) \cdot CH_2S-SCH_2\ CH(NH_2)COOH$. As the cystine is broken down sulphur is liberated and dissolved and unhairing will not occur until this dissolved sulphur value reaches a definite minimum for any given skin. The time required for unhairing may be shortened by raising the temperature of the lime solution or increased by lowering the temperature, but, at the point of unhairing, the dissolved sulphur values are found to be the same, regardless of temperature.

Proceeding to the second question: the reason for the mellowness of reused lime solutions. Here again the possible rôle of bacteria and enzymes, as well as of the ammonia dissolved in the lime solution due to bacterial digestion of the skin before it entered the lime, were considered to be possible contributing factors. Yet practice showed peculiar anomalies: supposedly mellow limes were not always mellow and behavior in liming often varied from skin to skin. Nor could the amount of ammonia present be taken as either an explanation for nor as a measure of mellowness, while bacteria and enzymes—as shown above—were eliminated. It was finally found that the mellowness or lack of mellowness of a lime solution was due to the presence or absence of primary amines. If a primary amine, methyl amine for

example, is added to an unused lime solution a "mellow" lime results. Further experimentation has indicated that the action of the amine is probably one of catalysis of the decomposition of the keratin, which explains why the quantity of amine present in mellow limes may be extremely small and yet so markedly affect the speed of reaction between the lime and epidermis.

The third question—the source of the amine—was next answered. If freshly flayed skin (where bacterial digestion is practically absent) is passed through the lime, little or no mellowness results. If, on the other hand, the proteolytic bacteria present upon the skin are allowed to digest it, mellowness in liming will result. The greater the extent of bacterial digestion the mellower will be the lime. In other words, the amine is formed by bacterial digestion of valuable skin proteins. This may be illustrated by the action of certain proteolytic bacteria upon one of the skin amino acids—glycocoll—which is, by them, decomposed into methyl amine and carbon dioxid: $CH_2 \cdot NH_2 \cdot COOH = CO_2 + CH_3NH_2$.

A scientific understanding of the materials and processes of tanning is of vital importance to the industry, since such knowledge must underlie all advances in the methods of manufacture and the production of more and better leather from a unit of raw material. This is of especial importance at the present time because the world's population of animals whose skin may be used for leather has not kept pace with the increase of its human population. And fundamental knowledge gained in the science of the tissue skin and the materials with which it is tanned can not fail to be of value in the field of so-called pure sciences.

FALLING WATER

By Professor O. D. VON ENGELN

CORNELL UNIVERSITY

> And dashing and flashing and splashing and clashing;
> And so never ending, but always descending,
> Sounds and motions for ever and ever are blending,
> All at once and all o'er, with a mighty uproar,
> And this way the Water comes down at Lodore.

THUS wrote Southey to please his children, who demanded a poetical description of the waterfall they knew. Although the form of the versification is such that even the authors of guide-books venture to indulge themselves in literary criticism by referring to the "jingling rhymes," it is nevertheless true that "The Cataract of Lodore" is most remembered of Southey's pieces. Its jingling rhymes give expression to sensations that not only those of tender years, but grown-ups as well, experience when standing beside a waterfall.

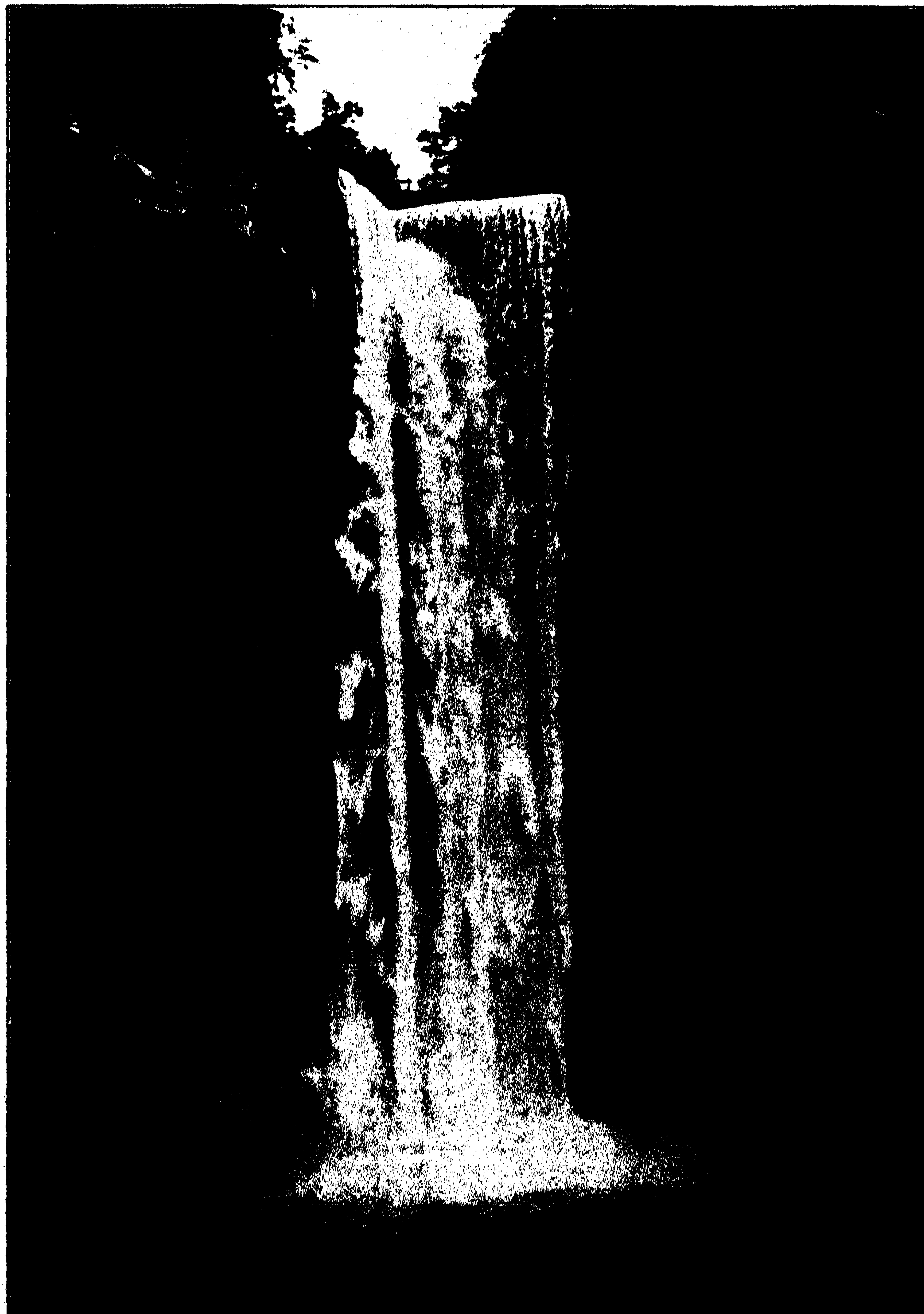
Water in any form, a brook, a river, a lake, the sea, gives charm to the landscape in which it appears. There is a suggestion of cool depths. Beautiful reflections are caught in the water mirror. One is attracted to boating over the limpid surface. These ideas are not commonly put into words but they are nevertheless present in the background of consciousness. But we go deliberately to places where water comes to life, runs, foams, leaps and pours over rocky brinks; plunges and disappears into the depths of shadowy glens. There we anticipate music and mystery, potency of motion in a ceaseless rush.

Our interest in waterfalls would probably become merely passive, however, if these offered nothing further than the spectacle of a tumbling stream. A visit to one or two waterfall sites would satisfy curiosity. Instead of such a reaction we note that the prospect of a visit to a new cascade quite invariably gives anticipatory pleasure, pleasure which is enhanced by realization. We may very properly inquire why such active interest should continue to possess us, whereas we so easily become indifferent to other aspects of scenic beauty.

The answer to this question, stated concisely, is that the form and setting of the falls attract us as much or more than does the tumbling water. In the first place there are several great classes of waterfalls. Each of these classes has a distinctive aspect. One who travels widely and sees waterfalls in many regions will become aware of these greater differences. But in any given district numerous waterfalls of a single type will each one be unique in the details of its form. There will be all gradations in volume from a Niagara to a woodland brook. And where water falls, it is from a rocky brink that it leaps, and into a rock-walled depression that it plunges. According as the nature and the structure of the rock vary, there can be significant large differences of form and a thousand differences in details in one general type of waterfall. It is the infinite variety in waterfalls that makes their appeal unfailing.

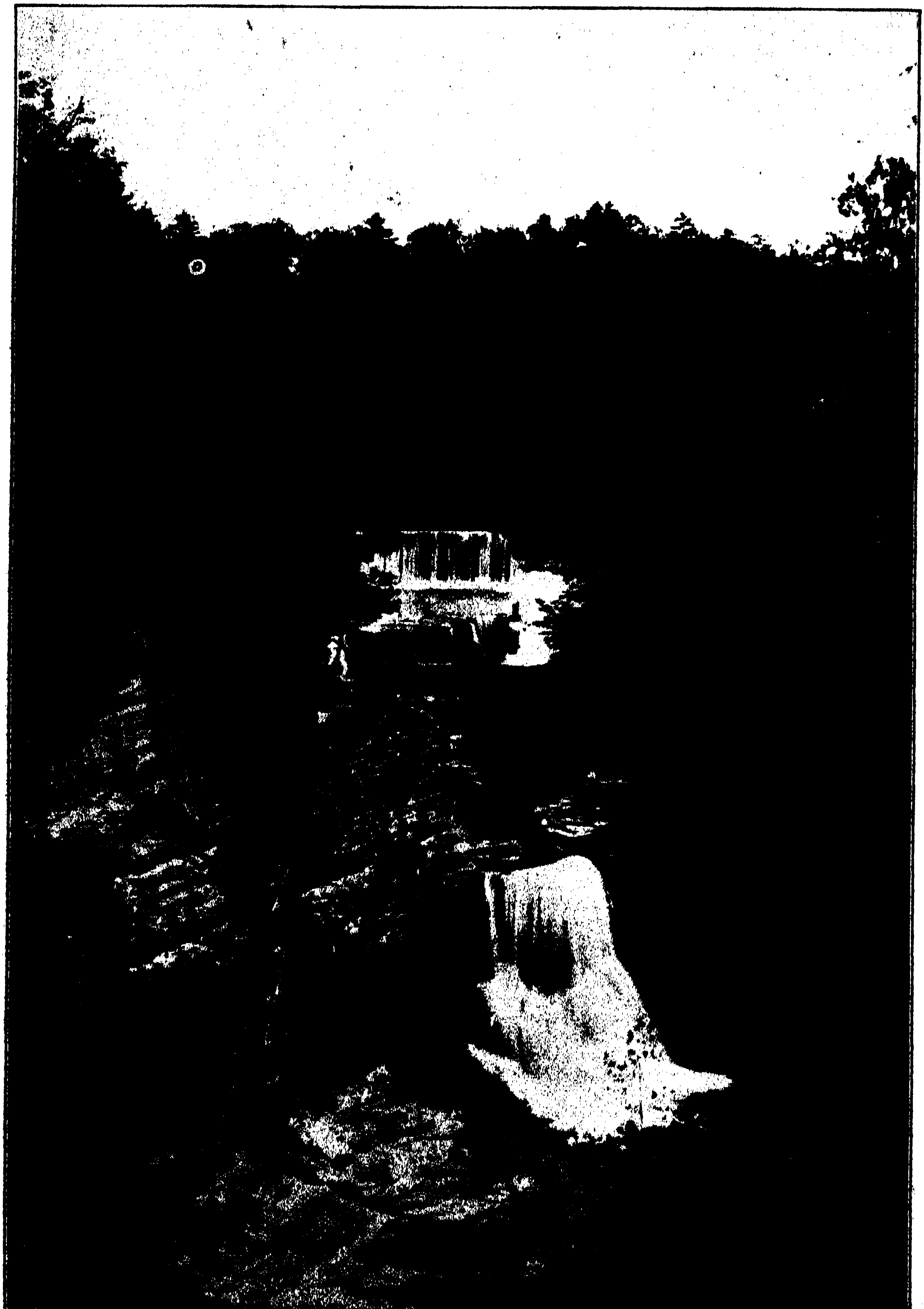
Once this fact is appreciated we begin to wonder about the origin of waterfalls and seek to know the cause of each variation in aspect. And if we can learn to read the answers to these questions we become even more anxious to visit new waterfall sites, for it is found that each example illustrates a new phase of the general story.

Waterfalls develop most commonly where a stream first encounters very resistant rock in its course and then flows



TAUGHANNOCK (TAGHANIC) FALLS, NEAR CAYUGA LAKE, NEW YORK

TAUGHANNOCK FALLS HAS NO CONSPICUOUSLY STRONG CAP ROCK, HENCE NO EAVES, BUT THE MARKED DEVELOPMENT OF JOINTS AND THE READY YIELD TO WEATHERING OF THE SOFT GENESEE SHALE BELOW THE CREST HAS PERMITTED THE PRONOUNCED SPRAY EFFECT (PARTIALLY SHOWN IN THE PICTURE) TO OPEN A WIDE AMPHITHEATER BELOW THE FALLS.



TRIPHAMMER FALLS, FALL CREEK, NEW YORK

HERE THE EFFECTS OF THE TWO TYPES OF WATERFALL RECESSION APPEAR IN ONE PICTURE. THE UPPER FALLS ARE RECEDING, LIKE NIAGARA, DUE TO PLUNGE POOL GRINDING; THE LOWER FALLS RECEDE IN PART BY PLUNGE POOL GRINDING, IN PART BY WEATHERING WITH OVERHANGING EAVES, THUS GIVING RISE TO AN AMPHITHEATER.

over weak rock that is easily and quickly rubbed away. Niagara is the greatest exhibit of this type. The abrasion wrought by the sand and silt carried along by the current only very slightly affects the durable rock upstream from the waterfall site. But the same current passing over the weak materials downstream very quickly scours out a deep channel. Then a waterfall comes into being where the strong rock ends and the weak rock begins. Once started the falls perpetuates itself, indeed it tends to make the falls effect more pronounced as time passes. The water now plunges on the weak formation when previously it had only flowed over it. Above the falls the strong rock continues to be only slowly worn by current scour.

But even where a falls is made progressively higher by the always more rapid rubbing away of the weak rocks downstream the durable rock at the brink of the falls does not escape all destruction. The pounding of the water at the base of the falls tends to excavate a pool at that point. As this pool is enlarged laterally it undercuts the strong rock. When such undermining has proceeded to a condition that deprives the crest rock of adequate basal support pieces of the durable ledge at the brink of the falls break off. Such pieces are seized upon by the churning waters in the basin below the falls and whirled about. Thus boulders from the brink become tools used to accelerate the undermining process. In consequence of these conditions the crest line of the falls may be caused to recede upstream at a surprisingly rapid rate.

In our literature of national humor, Niagara, the majestic, is journey's end of the newly wedded only. In fact, however, Niagara as the outstanding example of the strong rock-weak rock, horizontal layer type of waterfall always has attracted thousands of other visitors, persons of consequence and of no consequence, besides bridal couples, and no doubt always will be a goal for legions of sightseers. Niagara is also representative of one extreme in aspect that this type of waterfall shows. At Niagara the volume of water going over the crest is tremendous; the supply unfailing. Night and day, year in and year out, in unvarying quantity those thousands of tons of water per second hurl themselves over Niagara's brink. The undermining effect is extraordinarily rapid in its action. Within historic time the crest of the falls has been noted to go back hundreds of feet. The measured rate of recession at certain points along the crest is over five feet each year.

In consequence of these conditions one sees at Niagara a river flowing almost on the surface of the land above the falls, a heavy curtain of water going over the falls, and downstream a gorge seven miles long with nearly vertical walls of rock on both sides for all its length.

This gorge is the significant feature of the Niagara waterfall occurrence. We are led to inquire why the gorge valley below the falls should here be so prominently developed. The answer is that the rapid recession of the crest of the falls that we have been able to note and measure within historic time has been going on practically uninterruptedly since the time when the falls first started at Lewiston. So rapid is the recession that the processes of weathering: frost, rain, solution and decay, which are competent to cause marked roughening of stone, polished by man for monumental purposes, within a few years, have not effected enough crumbling to cause the gorge walls to lose their cliff form in any part of the gorge in the time since the recession of the falls first gave them existence. To-day the rocks of the gorge sides stand quite as straight-walled, steep and bare as when the falls crest passed each point of the length of the gorge in its hurried recession.

TINKERS FALLS, LABRADOR HOLLOW, NEW YORK

HAS BIG OVERHANGING EAVES. THERE IS A WIDE, DEEP, STEEP-WALLED AMPHITHEATER IMMEDIATELY BELOW THE FALLS.

For the other extreme in form let us look at a falls which is as obscure as Niagara is well known. At Tinkers Falls, Labrador Hollow, in central New York, we find only a slender stream, a woodland brook pouring its waters over a rocky crest. The same conditions of rock arrangement that exist at Niagara prevail here also: the strong rock on top, the weak rock below and horizontal layering. But what a difference in waterfall aspect! It would almost seem that this falls had planned to feature its rocky setting in a big way in order to compensate for its punier volume. It shows its cap rock boldly and distinctly making clear how strong it is. All Niagara's cap rock is hidden at the falls. Then it makes up for a long steep-sided gorge by producing a great amphitheater beyond and around the falls. It causes the cap rock to overhang as tremendously wide eaves so that one can go behind the falls and look at the falling curtain of water in front.

The site seems so completely sheltered from storm and wind that a primitive family might be expected to select it for a home place. Such a family could dig itself a roomy cave into the soft rock underneath the cap rock of the falls, build a fire on the sheld in front of the cave and let the rest of the world go by. But as a permanent residence such a place would have its disadvantages. It looks well on a sunny day. It even makes a fascinating retreat when one is caught in the woods by a summer shower. But the fact of its development and existence is a clear indication of certain difficulties. The overhanging caves are plain evidence that action of weathering is here more rapid than are the effects of erosion due to the plunge of the water. Instead of the cap rock being undermined at the base of the falls by the swirling of water in the pool and the resulting grinding action, as at Niagara, the retreat of the crest line upstream here is due primarily and almost exclusively to the crumbling of the weak underlying rock through subaerial processes. The thin falls make much spray. The rocks at the side and behind the water curtain are commonly damp to wetness. That dampness would make the place generally rather unattractive, not to say unhealthful, as a home site. It also serves to make the weak rock dissolve and decay. Then, in winter, by continuous addition and freezing, the wet from the spray builds up great ice masses all around the falls—not exactly ideal conditions at the door of one's home. The weight of this ice pulls rock fragments out and down.

Thus are developed the big overhanging eaves. The semicircular swing of the rock canopy extends so far on either side of the falls that the big amphitheater pit results. The amphitheater is surprisingly symmetrical. Probably changes in wind direction bring about an almost uniform distribution of the spray toward each side. This effect is commonly helped by the sun on bright days. In the morning the sun's rays fall on the rocks of one side, in the afternoon on the rocks of the other side of the amphitheater. As the rock becomes hot it causes the air in contact with it to expand, and a convection current is set up. A local wind, sometimes quite strong, develops. The air, and spray with it, moves from the cool area at the base of the falls toward and up the heated wall. In the afternoon the effect is directed toward the other side. Thus the rock walls below the falls are alternately heated and cooled, made wet and permitted to dry. Such rapid and numerous changes in conditions are particularly conducive to the crumbling of rock. It is obvious that the crumbling can not proceed indefinitely far back behind the falls.

At some distance back (how far will depend on the nature of the cap rock: how strong it is of itself; how much broken by joint cracks it is) the eaves, deprived of adequate support, will crash

FALLS NEAR SPAFFORD LANDING, SKANEATELES LAKE, NEW YORK

HERE SEVERAL STRONG LAYERS ACT AS CAP ROCK FORMATIONS. SLOW RETREAT OF THE CREST PERMITS WEATHERING PROCESSES TO OPEN THE GORGE BELOW THE FALLS TO V-FORM AS RAPIDLY AS THE RECESSION OF THE CATARACT TAKES PLACE. THE OVERHANG IS SLIGHT AND THERE IS NO PLUNGE POOL.

down and the site of the falls will be established at a new point upstream.

It is easy to imagine these consequences and to contemplate a number of such crashes in succession causing the site of the falls to retreat rapidly upstream. Indeed, as natural processes go, the crumbling undermining here in progress is rapid. But in actuality, as measured by years, it is a slow business. The primitive home underneath the eaves might not be disturbed by a crash for several generations. Proof of such stability is to be derived from the fact that the slow erosion and transportation of the stream below the falls and the crumbling which accompanies these processes have been competent to dispose, quite completely, of the waste of earlier crashes and to open out the valley to a broad V form with much more gently sloping sides than those close up to the amphitheater.

Here we may make another interesting deduction. Although it is easy to see that the opening of the valley took much time, still a large number of the infrequent crashes must have occurred in order that the cut and amphitheater we are looking upon might be developed. Then the thought comes: this stream must have been flowing in the same volume, these processes must have been acting in the same way and at the same rate for ages and ages. We have perhaps been taught that the life-span of man is but a fleeting instant in the measure of all time, but we are confounded, despite this learning about human inconsequence, by such indubitable evidence of hoary age and perfection of stability manifested in a woodland brook and its waterfalls!

At another waterfall, quite small, unnamed, situated in a ravine which is cut into the eastern slope of Skaneateles Lake in New York, this story of variety in waterfall form and recession and of time, ages long, is given another turn. There the volume of water is, if anything, less than at the site we have been considering. Further, the strong cap rock is split up into several layers, with weaker beds of rock between them. Also, the weak rock downstream is not so very weak. So all in all the conditions for the production of a waterfall are reduced quite to their lowest dimensions. The division of the cap rock into several members makes the development of eaves difficult. The strength of the weak formations downstream altogether stops plunge-pool undermining. Accordingly we see no overhanging rock, no amphitheater. The falls appears simply as a straight line wall across the ravine. Here, in other words, weathering, a general term applied collectively to the various processes that cause rock to crumble, almost keeps pace with waterfall recession. The ravine is widened out to a V as fast as the brink of the falls moves back.

It becomes quite clear, therefore, using only these three examples as illustrations, that in the type of waterfall described, the type which is most common, great differences in form result according as the recession of the crest line takes place rapidly or slowly. The rate of recession in turn is noted to depend on the variable factors of volume, relative thickness and massiveness of the rock formations, relative durability of the cap rock and the underlying weaker beds. With so many variables each possible in so many degrees it is also quite obvious that the aspect, the scenic attractiveness of each waterfall site will be different. "See one and you see all" is a rule that distinctly does not apply to waterfalls. Yet the elements that bring about the differences in waterfall form are easily appreciated and understood. The waterfall enthusiast may apply them to each occurrence when he sees it for the first time. He will gain an intellectual satisfaction from the appraisal he makes and can thus happily supplement the esthetic thrill which even the callous tourist experiences at the sight of falling water.

THE RÔLE OF RELIGION IN A SECULAR AGE

By Dr. HARRY ELMER BARNES

I

THE struggle between science and religion to-day is but one phase of our general cultural complex in which we have, on the one hand, a very advanced scientific and mechanical civilization, while our ideas and institutions, on the other hand, retain the taint of primitivity and superstition.

The scientist is bound to come into contact and conflict with orthodox religion. In the first place, it is continually hampering his activities in different ways and by various methods. Even to-day he has to devote a part of his attention to protecting himself against anti-evolution laws and blasphemy laws. Then, if the scientist is an educator and has any self-respect, he desires to have his views of the nature of the cosmos, the universe, man and society dominate in the minds of men. The orthodox conceptions of the universe and man clash at every point with the scientific. The conventional religious view of the universe is one in which the earth is regarded as the largest and most important entity in the cosmos and the sole center of divine interest. Man is portrayed as primarily a theological exhibit who should be chiefly concerned with saving his immortal soul and securing an eternal life in the world beyond. Society is looked upon as the environmental equipment essential to test out man's fitness for salvation. Its codes and institutions are believed to have been divinely revealed and to be above legitimate criticism by man. The good life is not that which will make man most happy here on earth but that form of conduct which will make eternal salvation absolutely certain.

The scientific and esthetic conception is the direct opposite of all this. In the first place, we should make reference to the contributions of the evolutionary view-point. Here the first striking implication to be noted is the complete revolution of our time perspective which the evolutionary conception has made necessary. In the place of a very brief period of some six thousand years for the age of the earth and all living matter, we must reckon with a time conception which defies both the human imagination and our conventional standards of measurement. Hundreds of millions of years must be assigned to the earth in a minimum estimate, whereas the sun had passed its maximum radiance before the earth was separated from it in whirling particles. When one turns to the probable amount of time involved in the evolution of the cosmos, the conceptions and standards which prevail in measuring time for earthly purposes seem quite trivial and inadequate. Indeed, we may have to admit that, in the new cosmic time perspective, the very notion of time as we understand it may be nothing more than a convenient human illusion. Einstein and others have, indeed, suggested that time and space are but incidental manifestations of energy. The age of man in this new time perspective, instead of being coexistent with the duration of the earth and all the heavenly bodies, must be regarded as but the briefest trifle in earth history, to say nothing of its utter insignificance in terms of cosmic history.

Along with the revolutionized time perspective has come the dynamic notion of change as the vital and universal

principle of cosmic development. In the place of the older static notion of a perfect creation a few thousand years back, with but slight subsequent alteration of the nature of the heavenly bodies, the earth and its organic life, we have to recognize that change appears to be the most vital law of cosmic development and to realize that there is no such thing as a fixed and changeless condition to be observed in the universe. Everything is in a state of alteration, some of this being in the way of development and progress while other changes definitely manifest disintegration and devolution. We have, then, the conception of a dynamic and ever-changing universe in the place of the static outlook of a half-century ago.

A third vital implication of evolution is the fact that man has been demonstrated to be, not a theological exhibit a little lower than the angels or higher than the earthworm, but a highly organized biochemical entity, at the present time the temporarily dominant type in the animal kingdom inhabiting this planet. There seems to be nothing about human life or behavior which is in any sense unique and not susceptible of explanation according to naturalistic laws and principles.

The implications of modern astrophysics are absolutely destructive of the orthodox version of the Christian epic, as well as of orthodox Judaism or any other type of geocentrically circumscribed religion. The old view of God as a venerable and somewhat gigantic being, resembling man in every detail, frequently taking up his abode upon this earth and being at times accessible to call from his more faithful supporters; the notion of the earth as the chief product of the creative endeavor of God and the supreme object of his divine solicitude; and the view that Christ could have been in any literal sense "the only begotten son of God" offered up as a vicarious sacrifice for the sins of a small group of rather backward peoples dwelling at the extreme eastern end of the Mediterranean Sea—all such conceptions become easily and immediately recognizable as primitive anthropomorphic and geocentric misapprehensions.

Yet, while the earth is reduced in cosmic importance, its significance for man becomes greatly enhanced. We stand or fall entirely with our planet. We are alone in the universe of universes and all that counts for us is what takes place here on earth. Modern astrophysics, then, provides the framework for a truly mundane and secular outlook with respect to human life. We may survey the heavens and thereby cultivate terrestrial humility and cosmic reverence, but in our life aspirations and achievements we are thrown back solely upon our earthly habitat. Man can no longer be regarded as "the lord of all creation," but shrinks to the position of the highly organized mammal which has just now succeeded earlier species as the definitely ascendent form of organic life now existing on our planet. But if man dwindles in cosmic importance, he has been elevated with respect to his own pretentions. From now on we must realize that human problems are the only valid problems which face man and that the increase of our happiness is the only vital issue which confronts us. Society can not continue to be looked upon as the testing-grounds for the scheme of salvation but must be viewed as the means whereby man may, through cooperative endeavor, work out institutions and cultural traits designed to make his mundane existence ever more efficient, decent, happy and beautiful. The criterion of the good life is its relative contribution to the realization of such a mundane ideal. In the new outlook there would seem to be no good but human desires and their satisfaction, though we should recognize that the satisfaction of

desires may well express themselves in ever higher forms of manifestation and must be guided ever more perfectly by science and esthetics.

Now, in so far as the scientist has any pride, self-esteem and passion for enlightenment he must naturally desire to have his view of the universe and man prevail over the ancient religious interpretation which contrasts so directly and markedly with the scientific version. He may further legitimately demand that if we are to retain any conception of God, then that interpretation must be made compatible with at least the rudiments of the scientific knowledge concerning the universe and man.

An even stronger motive for a scientific criticism of orthodox religion may arise from the apprehension of the scientist that human misery and suffering are being increased and perpetuated by orthodox religion and from the belief of the scientist that he can reduce this suffering and increase human well-being. The scientist looks upon the great volume of fears and superstitions which obviously have not the slightest scientific validity, but, nevertheless, continue to influence countless millions. He notes the expense connected with the great organizations devoted to exploiting these superstitions and imaginary fears and reflects upon what might be done with such resources of money and potential intelligence in advancing the secular welfare of mankind. He considers the unhealthy and unhappy mental states which afflict millions in America to-day because of false theories of life inculcated in earlier ages when man was solely concerned with salvation and when he had no command of the scientific knowledge essential to the understanding of what constitutes a healthy and happy life here on earth. He surveys the suffering due to the widespread contraction of mental and nervous diseases which are a product of this same unscientific conception of desirable human behavior. He observes the wide prevalence of serious physical diseases that are to-day extant solely because of that prudery born of religion which prevents us from undertaking adequate education in regard to venereal prophylaxis. He contemplates the unspeakable suffering and the many deaths resulting from our barbaric laws regarding abortion.

He discovers families in dire poverty, and the world approaching the saturation point in population growth which may well turn humanity back into barbarism, as a result of the necessity for a struggle for bare existence—all on account of an archaic religious prejudice against birth control and population limitation. The candid observer of modern conditions must further note our barbarous divorce laws which degrade the institution of marriage and, in hundreds of thousands of cases, rob the family of the essential elements of freedom, sentiment and independence. They make it necessary to deal with the family as a theological entity—something which God has joined together—rather than as a secular institution designed to further social well-being. Likewise, he can not escape taking cognizance of a fanatical Prohibition scheme, parading under the guise of a "noble experiment," but actually debauching American morals and political loyalty, stimulating crime and corruption and paralyzing our system of criminal justice, with results as fatal to real temperance as to civilized modes of utilizing alcohol to promote human happiness. He observes many unscrupulous employers exploiting supernatural religion as a socio-economic anesthetic, thus enabling them to escape their decent obligation of adequate wages and satisfactory working-hours. By aiding the priesthood in their effort to perpetuate superstition and other-worldliness, they are reasonably successful in inducing the laborers to accept their

harsh and miserable life here on earth in the hope of better things in heaven. If he possesses, in addition to scientific knowledge and acumen, some degree of esthetic appreciation, the scientist must also deplore the ugliness, brutality and wastes which are inevitable by-products of the superstitions, prejudices and solemnity of orthodox, supernatural religion and its puritanical tendencies.

Once one observes these matters in a thorough fashion he is not likely to continue to believe that the scientists can persist in ignoring religion. If he is thoroughly conversant with contemporary conditions and issues the scientist will also contend that supernatural religion must be further criticized on the ground that it absorbs the intellectual efforts of many able men whose talents we need for the all-important task of coping with the increasingly complex problems of our material culture and our social institutions.

The above facts also constitute an effective rejoinder to the modernists who hold that we have passed through a revolution in religious thought and contend that the case against Fundamentalism is but an attack upon a bogy or a man of straw. In the first place, the theological revolution has affected only a few of American religious communicants—the majority still remaining loyal to the old concepts and dogmas. More significant, however, is the fact that modernist theologians, for the most part, support the Fundamentalist sociology, and, after all, the most important issue is that of the social effects of religion.

II

In entering upon the subject of the conflict of science with religion it is desirable for clarification to understand what type of religion is being discussed. We must be frank enough to admit that there is an eternal conflict between any true science and the type of religion represented by men like Cardinal Hayes, John Roach Straton, the late Mr. Bryan, Dr. Howard A. Kelley and the like. Between secular science and eschatological supernaturalism there can be no common ground, and neither group of adherents need be expected to give quarter to the other. One trusts in observation and is interested in secular or mundane happiness; the other rests on faith and is concerned with spiritual salvation in the world to come. The fact that Pasteur, Mendel and others have been both religious and scientists is of no avail in attempting to demonstrate that orthodoxy does not conflict with science. Mendel's researches were buried and had no significance until they were rescued by a non-Catholic evolutionary biologist. There was nothing in Pasteur's studies of putrefaction and pathology that raised any question of the conflict between science and supernaturalism. Let the question of birth-control be raised and Cardinal Hayes does not turn to his Mendel for his pronouncements but thunders forth that "little children come trooping down from heaven." Let the Catholics or the Fundamentalists of Protestant persuasion point to a single devout scientist of importance whose researches have dealt with problems which might directly jeopardize the standing of orthodoxy.

The conflict of science with devout modernism as represented by men like Dr. Fosdick is much less than that with orthodoxy. In many ways there is entire harmony of outlook and purpose. The criticism which the scientist would level against modernists like Dr. Fosdick is that they appear to keep the nomenclature and phraseology of the older orthodoxy while accepting the findings of modern science. They still preach in the name of Yahweh and Jesus. Yet Dr. Fosdick has himself presented a withering, indeed, extinguishing critique of Yahweh; and his theological learning,

scientific knowledge; social experience and esthetic appreciation far surpass any pretensions or achievements of Jesus in these fields. Therefore, he can speak in his own name and on his own authority with far greater effect than he can preach in the name of Yahweh and Jesus.

The scientist would also deplore the retention of the term "spiritual" by the average modernist as implying something apart from the secular and incapable of scientific scrutiny and measurement. It would be far better to discard this anachronism and use the terms psychological and esthetic for what the modernist really means by spiritual. The scientist can not concede the existence of any mysterious spiritual entity apart from the forces and tendencies which he studies. The scientist, natural or social, would also insist upon the relinquishment of another ancient animistic conception, namely, the category of "sin." Sin connotes a supernatural conception, namely, the violation of the explicitly revealed will of God. To-day, when we recognize that there is no method of proving God's existence, to say nothing of his nature and will, it is obvious that we can not possess the prerequisites of sin. This archaic term should be abolished, and all forms of antisocial action should be isolated and differentiated on the basis of their mundane results. No act can be regarded as bad unless it reduces human happiness and the beauty of life. Acts which are thus harmful should be rechristened with contemporary secular terms like crime and immorality. The notion of sin and of the supernatural origin of morality only confuses, complicates and obstructs clear thought and constructive action in these fields.

Likewise, in regard to the reconstruction of social conditions, the scientist would object to the effort of men like Sherwood Eddy to justify their brave struggle for social justice on the ground that it conforms to the teachings of Jesus. We herewith reproduce the authoritative summary of Mr. Eddy's truly noble principles of Christian socialism, which embody a splendid conception of human altruism and social reform but is justified through an appeal to Jesus' way of life:

Believing in Jesus' way of life and in his all-inclusive principle of love as the full sharing of life, I therefore determine to apply this principle in all the relationships of life:

(1) To live simply and sacrificially, avoiding waste and luxury. To make the purpose of my life the making of men rather than the making of money. Not to grow rich in a poor world by laying up treasures for myself but to share all with my fellow men. To apply the golden rule in all my relationships.

(2) To practice brotherhood toward all. To remember that every human being is a person of infinite worth, deserving the fullest opportunity for self-development. To participate in no secret order or fraternity if it tends to exclusiveness, prejudice or strife. To seek justice for every man without distinction of caste or color.

(3) To make peace where there is strife; to seek to outlaw war, "the world's chief collective sin," as piracy and slavery have already been outlawed, substituting a positive program of international justice and good will.

(4) To redeem the social order; to test its evils by the principle of love and fearlessly to challenge them as Jesus challenged the money-changers in the temple. To endeavor to replace them by the constructive building of the new social order, the Kingdom of God on earth. If a student, to apply this purpose immediately to the problems of our campus; to seek education as training for service rather than the mere enjoyment of privilege, the attainment of grades or the achievement of cheap "success"; to tolerate no dishonest practices in classroom, athletics or college elections; to maintain no relationships with my fellows, men or women, which violate absolute purity or debase the divine value of personality. Since I realize my inability to achieve this way of life unaided:

(5) To seek a new discovery of God which will release within my life new springs of power such as men in the past have experienced when they rediscovered the religion of Jesus.

In order to carry out this five-fold purpose, I will seek immediately to associate myself with others for the purpose of study and experi-

mentation in the realization of Jesus' way of life.

Now Mr. Eddy has traveled widely through the world, observing all kinds of labor conditions and social situations, and he has counseled long with the foremost socio-economic experts now alive. Therefore, his own views on modern social and economic conditions should command more respect than those of Jesus who lived a restrained and provincial existence in a very backward economy. In other words, we should like to hear more and more of what Dr. Fosdick and Dr. Eddy have to say on their own authority and less of their palpably hopeless effort to discover a consistent and relevant social philosophy on the part of Yahweh and Jesus and to apply this to conditions quite different from ancient Palestine in the time of either Jesus or Moses. Of course, if Drs. Eddy, Fosdick, *et al.*, retain the old nomenclature merely for its pragmatic value in working with those familiar with and attached to this terminology, then there is little to criticize in their conduct.

When we come to Unitarian humanism, as upheld by men like Drs. Dietrich, Slaten, Holmes, Reese, Robinson, Randall and the like, and liberal esthetic Episcopalianism, as represented by such men as Drs. Reiland, Humphries, Guthrie and others, the conflict between science and religion is relatively slight. Both groups accept the same scientific view of the cosmos, the universe, man and society, differing only in their respective interests and life endeavors. This advanced modernism is really more of a social philosophy and a branch of ethics and esthetics than anything resembling the old savage anthropomorphic and geocentric orthodoxy.

On one important point, however, even some of the exponents of so advanced a position as Unitarian humanism must modify their views if they are to be compatible with science. What we have in mind is the doctrine of the freedom of the will. In Dr. Curtis W. Reese's excellent summary of Unitarian Humanism ("Humanism," pp. 38–9) he says: "The moral life begins with freedom to choose or not to choose a line of action; and no moral significance can be attached to any action in the absence of this freedom." To be sure Dr. Reese tries to identify this moral freedom with the control of the emotions by an intellect well stored with knowledge. This, however, confuses two quite different issues and problems. Further, knowledge appropriated and interpreted by the intellect is as much involved in the deterministic process as our emotional impulses. The very fact that we are able to control our life on the basis of knowledge, as Dr. Reese insists, logically implies that we are not free from the determining effect of this information. What Dr. Reese actually means is that we should more and more thoroughly control our life on the basis of reliable information regarding the good life on earth which has been amassed by natural, psychological and social science. He should not contaminate and defile this noble aspiration by in any way identifying it with the archaic theory of free will, which has no more standing before modern psychological science than the Hebraic "firmament" has in the light of the astrophysics of Jeans, Einstein, Shapley, Eddington and Dingle.

It need scarcely be pointed out that there is no basis for essential conflict between science and the Christian socialism expounded by men like Norman Thomas, Bouck White, Upton Sinclair and others. These men derive the justification of their views from secular rather than supernatural considerations. The only issue is the degree to which their opinions and programs square with the best social and economic science. The question of the clash between supernaturalism and secularism does not emerge in this case.

It will doubtless be a splendid thing in this place to comment decisively and unequivocally upon one very prevalent but extremely disingenuous method of dealing with the critical attack upon orthodox religion, namely, to declare that it is all "old stuff," that it is generally accepted by all up-to-date theologians, that the attack is entirely unfair to the religious cause, and that there are really no more orthodox believers. The writer recognizes that the attack on orthodoxy goes back as far as the Egyptian emperor, Ikhnaton, about fifteen hundred years before Christ, if not before. He is not unaware of the attack upon orthodoxy by the Sophists and by Lucretius and the Epicureans. Further, he has made a special study of the assaults on orthodoxy by the Deists and other liberal theologians from 1650 to 1800. He is well aware of the heterodoxy of the Fathers of the Constitutional period in our own country. He is fully conscious, finally, that all he has stated in the recent controversy has been the common property of scientific students of religion for a generation.

All this is, however, quite a different thing from admitting that orthodoxy has no appreciable following in the country to-day and that to attack orthodoxy is to attack a bogy and a man of straw. The writer may offer the following in support of the thesis that this particular rejoinder to criticism is made in bad faith. During the last ten weeks the writer has probably received as extensive a number of representative letters on religion as any other person in the history of religious controversy in a similar period and he has been able to peruse a vast number of comments on the controversy in the press throughout the country. Now if his statements are to be condemned as "old stuff" and an irrelevant attack upon a non-extant body of belief, it is quite evident that those who would have the best reason for complaint on this ground would be the advanced religious thinkers of America—those who have passed farthest from orthodoxy. Yet, so far as the writer is aware, there has not come a single complaint upon this ground from the leaders of advanced religious thought in America. In letters or in the public prints the writer's stand has been commended as both timely and sound by such men as John H. Dietrich, Albert C. Dieffenbach, A. Wakefield Slaten, John Haynes Holmes, Alson H. Robinson, John Herman Randall, William Montgomery Brown, Archdeacon Humphries, Minot Simons, Henry Darlington, Charles Francis Potter and Rabbi Feinberg, to mention only a few representative names. On the other hand, those who have raised the "old stuff" dust have invariably been such wabbly modernists as William Adams Brown, H. E. Luccock, Henry N. Wieman, *et al.* Now we are not for a moment contending that the supporters of the writer's general position are right and flaunters of the "old stuff" slogan wrong. It is merely submitted that, if there were anything valid about the "old stuff" argument, the real leaders of the most advanced religious thought in America would be those who would be exploiting this position. The writer contends that the tendency to cry "old stuff" is an evasive method whereby conservative modernists hope to stem the tide of thoroughgoing criticism while offering to the public a gesture of pseudo-modernism.

III

We have just considered the matter of the conflict of science and religion from the standpoint of the different classes of religious leaders and the varying levels of religious beliefs. We may now examine the question briefly from the point of view of those scientists who have offered their services as liberal theologians and have declared that there is no conflict between science and religion.

Among the best known of these have been the eminent British biologist, J. Arthur Thomson, the brilliant American physicists, Robert A. Millikan and Michael I. Pupin, the prominent zoologist, Henry Fairfield Osborn, and the active Harvard geologist, Kirtley F. Mather. These men, and many others of their kind, have valiantly proclaimed that there is no conflict between science and religion. The most decisive and lyrical pronouncement is the following statement by Professor Pupin. It is the summary of an interview with him by Mr. A. E. Wiggam, the well-known popularizer of modern eugenic doctrine, and published in the latter's "Exploring Your Mind" (pp. 385–6). A more extended view of Professor Pupin's views may be discovered in his "The New Reformation," but the following summary by Mr. Wiggam will suffice to make clear the tenor of Professor Pupin's views:

Science is making us better Christians.

Science teaches us that the Universe is guided by an intelligent Divinity.

Science is teaching men how to cooperate intelligently with God; it is teaching men what his laws are and how to obey them.

Science is proving that the human soul is the greatest thing in the Universe, the supreme purpose of the Creator.

Science is leading us closer and closer to God.

Science has made us better homes and is teaching us how to make a better democracy and a better social life; it is thus preparing us for the greatest spiritual, artistic and intellectual life that men have ever known.

Science does not contradict belief in the immortality of the human soul.

Science is revealing God in greater and greater glory, and teaches us that in time we may possibly even see Him face to face. . . .

President Nicholas Murray Butler, of Columbia University, is reported to have said recently that, while talking with Dr. Pupin, he felt that he was witnessing the curtain being lifted upon a new and brighter world. I believe he would make you feel the same way, and I should like to convey that feeling to you through his own words.

The reconcilers from the scientific camp support their case in many ways. A familiar method, used by both Cardinal Hayes and Dr. Osborn in their condemnation of the writer's paper before the New York Academy of Medicine and the History of Science Society last December, is to enumerate an impressive list of scientists who were devoutly religious. The Catholic register will always contain Albertus Magnus, Roger Bacon, Copernicus, Galileo, Pascal, Mendel and Pasteur, but those who exploit it never call attention to the rudimentary and inoffensive observations of Albertus, to the clerical persecution of Bacon and Galileo, to the ecclesiastical intimidation of Copernicus, to the notorious compartmentalized mind of Pascal, to the fact that Mendel did not dare to give publicity to his researches in genetics and that they were recovered and disseminated through the efforts of non-Catholic evolutionary biologists, and to the fact that Pasteur's researches in pathology in no way raised issues which conflict with orthodox theology. This appeal to the list of names of religious scientists is both infantile and ineffective unless one examines each scientist individually, to discover the nature of his scientific work and his competence to discuss religion. The fact that a man may be an eminent physicist does not, in itself, entitle him to speak with any more authority upon religious questions than would the possession of an enviable record as a skilful blacksmith or plumber. There are a number of classical examples of internationally famous physicists and chemists who, with great gusto and pride, continue to conduct Sunday-school classes in orthodox religious circles. A great scientist, who is religious in an orthodox sense, either offers one more example of the notorious capacity of the human mind to compartmentalize itself and entertain mutually exclusive conceptions and attitudes, or is an illustration of the one-sided nature of our present-day education, which allows a

man to participate in the physics of Einstein and yet share the religious outlook of his Methodist or Baptist grandmother.

Professor James Harvey Robinson, in *Harper's Magazine* for September, 1928, has offered a very ingenious and convincing explanation of the so-called compartmentalized mind, in so far as it relates to the religious question. He holds that our religious beliefs and attitudes remain essentially on an infantile level, while we carry further the development of our psychic life in the field of science, technology, art, literature, and the like. In other words, the pious physicist is a person whose scientific views are on an adult plane, while in the religious field he is intellectually a youth in short pants. We may here quote the most cogent section from Robinson's views:

> Bryan exhibited through his life no more knowledge of religious matters than he could have easily acquired at ten years of age. Sermons of the commoner sort contain only what both preacher and audience accepted before they were grown up. Religion does not tend to mature in most cases. It is what we learned at our mother's knee. In later life we are preoccupied with business and amusement, and there is no time to keep up with the course of religious investigation, even if we had the slightest disposition to do so. Billy Sunday talks as a big husky boy to other boys and girls. Even distinguished scientific men solemnly discuss the relation of religion to science, when, if they but stopped to think, they would find that they were assuming that they know all about religion, without having given it much thought since childhood; although they would readily admit that after a lifetime's work they knew very little about science.

Dr. Thomson seeks to harmonize science and religion by the well-worn device of holding that science is supreme in the realm of the intellect while religion reigns over the emotions. As Professor Max Otto has well pointed out, this is no solution of the problem at all, for emotions do not function *in vacuo*, but associate their expression with definite beliefs, most of which have thus far in human history been contrary to the well-established facts of science. Indeed, the great value of psychological and social science lies in its potential service to the achievement of a scientific control and direction of the emotions. Professor Millikan resolves the conflict between science and religion by redefining religion in such a manner as to divorce it entirely from orthodoxy and to make it the inspirational adjunct of ethical dynamics. It is to be the great psychological stimulant to social well-being. As long as it is kept in general terms there can be no serious fault found with this suggestion. The difficulty comes in the recognition that this does not alter the fact that there remains a conflict between science and the orthodox cults which Dr. Millikan rules out as true religions. Yet one must remember that for one religious person who accepts Professor Millikan's view of religion as "the great dynamo for injecting into human society the sense of altruism" there are a thousand who enthusiastically espouse the primitive doctrines set forth by Cardinal Hayes and John Roach Straton. Dr. Osborn endeavors to prove that no conflict exists between science and religion by essentially the same means as does Professor Millikan. He strings along the threadbare list of devout scientists and then arbitrarily defines science and religion in such a fashion as to make religion accept the facts of science as a point of departure, something which orthodox religion is singularly loath to do in actual practice. Professor Mather employs another time-honored expedient, namely, that of denominating all the facts and processes of nature as essentially miraculous. He thus gives evidence of a sad lack of information regarding technical theological terms, for a miracle is by definition something which defies not only all existing but all probable future scientific explanation. Professor Mather errs by

confusing the term miraculous with the term impressive. We agree with Professor Mather that much, if not all, of nature is remarkably impressive, as one will perceive by recalling such a masterpiece as Huxley's lecture "On a Piece of Chalk." Yet that is quite a different matter from holding nature to be inexplicable. Moreover, miracles do not necessarily lead us to God and religion. Where science is baffled religion certainly can not offer reliable or assured guidance. With Professor Pupin's pronouncement we need not concern ourselves. It is nothing more than the explosion of a "will-to-believe" which could have been uttered by either Cardinal Hayes or Dr. Straton. It is purely a product of Professor Pupin's subjectivity and entirely incapable of scientific demonstration. It lets us know quite definitely how Professor Pupin personally feels on the subject of science and religion, but it takes us nowhere at all in getting at the fundamental issues involved. Wishful thinking does not take on the attributes of profound science or critical philosophy merely because it issues from a great laboratory physicist. It is still wishful thinking and nothing more.

In his important book, "The Nature of the Physical World," the eminent British physicist and astronomer, A. S. Eddington, admits that the new doctrines of electrodynamics do not lead us directly to a formulation of a specific and demonstrable conception of the new cosmic God, but, as a Quaker, he attempts to show how they enable us to formulate a defense of the old theological conception of free will or the freedom of human choice. As Bertrand Russell has well insisted, Professor Eddington is compelled to make certain gratuitous assumptions in regard to electrodynamics in applying its principles to psychology, but even more important is the fact that the question of the freedom of human choice is not an issue to be solved by an appeal to physics. It must be dealt with in relation to the processes of conditioned-response which are studied by psychology and sociology. If physics does not lead us directly to God, it is as patently evident that it does not lead us to the solution of the fundamental problems of human behavior. These are issues of an order as remote from physics as are the theological problems connected with God. If there can be no "quantum theory of God," as Professor Eddington admits, there can be no quantum theory of human behavior.

Finally, we may put at rest a venerable antique in the realm of apologetics, namely, the assertion, given wide currency by Andrew D. White, to the effect that the conflict is not between science and religion but between science and theology. This differentiation between religion and theology is one which has been abandoned by all up-to-date students of religion. Religion has three major manifestations: (1) the emotional thrill; (2) the behavior responses or ritualistic exercises engendered by this thrill, and (3) the conceptual interpretations and explanations of the religious thrill and the activities associated therewith. This third phase of religion is what has been known as theology. Therefore, theology can not be separated from religion. A theology is as tenable as the religious emotions and activities upon which it is based, and of which it is the rationalized explanation. If the religious thrill arises from unscientific assumptions and interpretations, then there is as much conflict between science and the religious emotions as between science and the theological formulations in that particular religious complex. If the activities and moral code growing out of the emotional basis of a religion are scientifically unsound, then there is as definite a clash between science and the religious rites and morals as between

science and the conceptual formulations. Inasmuch as theology represents the intellectual manifestations of religion, it is obvious that the most sharp and direct conflict comes between science and theology, but this is quite another thing from holding that there is no conflict between science and religion—that the issue is solely one between science and theology.

IV

The writer believes that, if humanity and civilization are to be preserved, we must, perhaps, have collaboration between science and an advanced secular religion. He readily concedes that neither Bertrand Russell, John B. Watson, Clarence Darrow nor George Dorsey has any need for God or religion in order to behave in a seemly or intelligent fashion, but, with half of the American population falling below the intellectual level of the dull normal type, we certainly shall require some form of social control beyond the appeal to pure intelligence. Further, there are many capable persons whose affinities are more with esthetic considerations than with matters of cold intelligence. For these types of human beings a social institution which could exploit human emotions and place them behind just and decent causes will prove indispensable. Such a secular religion would, of course, obtain its factual guidance from science, natural and social, but would aid science in the social application and execution of such facts.

In taking up the relation of science and God, it is evident to any informed person that the very elements of modern science, together with even the rudiments of an understanding of biblical scholarship, completely undermine and dispose of the biblical God, Yahweh. This necessitates a complete reconstruction of our views of Jesus, who owed his uniqueness to the claim that he was the only begotten son of Yahweh. From now on, Jesus must be studied as purely a secular and human religious teacher, concerning whose existence there is but slight information and regarding whose doctrines we have but fragmentary and often conflicting evidence. No contemporaneously minded person could pretend that the views of Jesus on any subject related to modern life can carry any such authority as those of Dr. Fosdick, Dr. Holmes, Dr. Reiland, Bishop McConnell or Rabbi Wise. This is a fact which the modernists have usually been loath to concede. They will admit the passing of Yahweh but cling to a view of Jesus that rests almost wholly on his alleged relationship to Yahweh.

As to whether a new conception of God may be constructed, the writer frankly admits that he does not believe it possible to arrive at any precise conception of the new cosmic God, if there be one. The whole search for a God is based on primitive human aspirations; the very facts of the physical universe, in terms of which the new cosmic God must be constructed, evade and baffle the limited human mind; we can only formulate notions of God in terms of our own experiences and categories, which are obviously wholly unsuited as a framework for the picture of the cosmic Almighty; and the basic hypothesis involved, namely, that all things must have a maker and a purpose, may well be a geocentric human illusion. In searching for a "first cause," we must remember that both "first" and "cause" are human inventions and categories which may have no general cosmic validity whatever. Therefore, it would seem that the quest for God in the new perspective is likely to prove futile. Yet it is a noble quest, certainly far more lofty than the search for an additional million dollars or a higher political office, and we can cast no aspersion upon those who carry on the search. Manifestly, in so far as the quest for a new

God helps on the abandonment of Yahweh it will be a great gain for humanity and civilization.

The question of the adequacy and sanctity of the ten commandments and the beatitudes is inseparably related to the problem of Yahweh, Jesus and the Bible which we have just discussed. They have no sanctity other than that which may reside in their validity. Some of the ten commandments, like the taboo on swearing and on Sunday labor, are obviously primitive superstitions. Other sound ones, like the commandment against killing, are incomplete and need elaboration in an age which is so highly versatile in its talent for murdering. Moreover, the ten commandments were devised for a very simple economy. If ten commandments were essential for primitive Palestine, then we should need five hundred for adequate guidance in twentieth century New York City. In short, the ten commandments are a primitive collection of social usages, having no more sacredness about them than the sound passages in the Code of Hammurabi. Many of the commandments should be obeyed to-day, but not because they occur in the Bible. They should be followed, if at all, only because they square with the needs of life in our era. The same may be said regarding the beatitudes and other sayings ascribed to Jesus.

The new religion, if sound and practicable, must rest on a thoroughly secular basis, secure its facts from science and conceive its ideals in terms of sociology and esthetics. It must become accessory to the new queen of the sciences, mental hygiene.

V

It follows as a matter of course that such epoch-making changes as we have described above, with relation to the status of orthodox religion in the light of modern science and critical thought, make necessary a searching reexamination of the place and function of the church in modern society. In the first place, the new view of matters makes it very evident that the clergyman can no longer pretend to be a competent expert in the way of discovering the nature, will and operations of the new cosmic God. If undertaken and solved at all, this is a problem for the cooperative endeavors of the natural scientist and the cosmic philosopher of the Dewey vintage. At best the theologian can only be a competent second- or third-hand interpreter of the facts and implications gathered about the cosmos and its laws by specialists in science and philosophy. In the old days, when it was thought that God might be reached and understood through prayer, sacrifice or revelation, the clergyman or theologian was indeed "the man of God" who could make clear the will of the Deity to believers. But now when God must be sought, if at all, by means of the test-tube, the compound microscope, the interferometer, the radium tube and Einstein's equations, the conventional clergyman is rather hopelessly out of place in the premises. Therefore, it is apparent that the intelligent and educated theologians must surrender their age-long pretension to special, if not unique, competence in clearing up the problem of the nature of God and His laws. They can at best be little more than ringside spectators of the observatory and the laboratory, doing their best in the way of an amateurish appreciation of what is going on therein.

Next to the revelation of the nature of God and his ways, the most time-honored function of the so-called "man of God" has been to unravel God's will with respect to human conduct and to inculcate the absolute and inflexible principles which should control personal morality, in order that the soul of the individual might be assured of an ultimate refuge in the New Jerusalem. This was a perfectly rational and logical function for

religion when it was commonly assumed to be axiomatic: (1) that the purpose of moral conduct was to insure the salvation of the soul, and (2) that the supreme and complete guide to moral living was to be discovered in Holy Scriptures. Neither of these fundamental postulates can be sustained today. There seems to be no ground whatever for the orthodox views of a bodily or spiritual immortality and the imminence of a literal heaven and hell. Hence, the basic objective of right living can no longer be regarded as the insurance of spiritual salvation. On the contrary, the fundamental purpose of the good life is to secure the maximum amount of happiness for the greatest possible number here upon this earth. Therefore, it is readily apparent that accurate guidance to the good life can not be sought in ancient Scriptures or provided by specialists in Holy Writ. The moral code of the future must be supplied by the specialists in mundane happiness, namely: biologists, physiologists, psychiatrists, educators, social scientists and students and practitioners of esthetics.

Some who frankly admit the incompetence of the clergyman and the theologian in the way of providing original and conclusive guidance to moral conduct contend, nevertheless, that the church can exercise a very valuable service in interpreting and popularizing the findings of the specialists in human happiness. This may be true, to a certain extent, but many qualifications would have to be added. Many phases of guidance to complete human happiness would necessarily be a highly technical and individual matter, to be handled by medical and other experts in relation to individual cases and problems, and would scarcely be adapted to comprehensive general interpretation or exhortation.

Some writers, among them the scientific reconciler, Professor Mather, contend that religion is essential to ethics in that it enables us to be "something more than ourselves," while scientific ethics admittedly can only enable us to make the most of ourselves. No answer is needed for this contention beyond asking Professor Mather to describe *just what is implied* in man's being more than man and just how a scientifically minded person could conceive of such an achievement. We further submit that it is quite enough of a problem to enable man to make the most of himself, and we further suggest that thus far religion has mainly succeeded in making us much less than ourselves.

A much better case can be made for the service which may be rendered by religion in inculcating an interest in and respect for such large and scarcely debatable moral conceptions as justice, honesty, pacifism, cooperation, kindliness, beauty, etc. Professor Kirsopp Lake has well stated the case for the desirability of having religion relinquish interest in sumptuary moral control and assume responsibility for the advancement of more profound and general moral principles:

> One man may find much comfort in tobacco, while another may injure himself by smoking; one may err by playing too much, and another by never playing at all. I doubt whether the men of to-morrow will try to interfere with each other on these points, knowing that the thing which matters is ability to do good work, and that one man can do his best work in one way, another otherwise. Many of the things Puritans condemn are strictly indifferent. The religion of to-morrow will recognize this, it will give good advice to individuals, but not lay down general rules for universal observance.
>
> On the other hand, it may have a sterner standard in business, industry and finance. It may insist more loudly that honesty applies to the spirit of business, not merely to its letter. It may even demand that men must be as trustworthy in advertisements, business announcements and journalistic reporting as they are in private affairs. For these are the questions of morals which are the issues of life and death for the future. They are not covered by the teaching of Jesus or of historic Christianity, for neither ever discussed problems which did not exist in their time. Some of the principles

which have been laid down by them will play a part in the solution of these problems but probably others will also be needed, certainly the actual solutions will contain new elements, and the religion of to-morrow will have to look for them.

One can scarcely quarrel with Professor Lake on theoretical and logical grounds, but there is an important practical consideration, namely, that the modern social and economic order is based to no inconsiderable degree upon intrigue, shrewd business enterprise, relentless competition, unreasoning patriotism and class selfishness. It can scarcely be expected that the custodians of the modern order, who provide the chief pecuniary support for our religious institutions and organizations, will contribute with enthusiasm to a movement designed to cut at the root of many of the principles and practices which they hold most sacred and indispensable. Before the church could achieve much in this field it would be necessary to organize and carry on a very definite propaganda of education in the principles of social ethics broadly conceived. Thus far, however, few clergymen so orientated and motivated have been able to maintain their position long enough to make much headway in this educating process. As far as the writer is aware, there has been no marked or organized effort to draft the services of Sherwood Eddy, Norman Thomas, Kirby Page, Bouck White, Ralph Harlow, Harry Ward, David D. Vaughan and others of their kind and induct them into the pastorate of great metropolitan churches.

The supervision of the church over recreation, which has in the past been exercised chiefly in the way of an arbitrary decision as to what are immoral and what are moral forms of recreation and in closely scrutinizing and controlling the activities of individuals in these fields, must now be sharply challenged. The orthodox religious criteria as to moral and immoral forms of recreation were not based upon physiological, psychological or social grounds, but upon theological considerations which have little or no validity in the light of modern knowledge. The church, having no competence in the matter of determining the nature of moral and immoral conduct in the light of modern secularism, obviously can not apply its decisions in this field to the realm of recreation. Recreation, like morality, with which it has been so closely associated in the past, is a field for the secular expert and must be handed over to biologists, medical experts, psychologists and social scientists. The church at most could scarcely go further than to proclaim the general desirability of healthy and adequate exercise and the exhibition of a proper spirit of good sportsmanship.

Another function of the church in the past which has received much support relates to its esthetic services. It is held that the ritual, pageantry and liturgy of the church provide a relatively economical and highly valuable esthetic service to humanity. This is, of course, an argument which can be far better justified from the Catholic standpoint than from the Protestant, the Protestant churches having given up most of the splendor of the Catholic service. This argument boils down to the allegation that the church is in a position to "put on a better show" for the populace and at a lower cost than any other comparable secular organization. While there is much to be said in support of this view in regard to the services of the church in earlier periods, it would seem that this function may be, and indeed is, now achieved more adequately and cheaply by various secular enterprises, such as the grand opera, the theater, the movies and various types of public pageantry. Further, many contend that the attitude of fear and awe generated by religious ritual and pageantry produces a fundamentally unhealthy state of mind which, to a large degree, offsets

the esthetic services contributed thereby.

Therefore, it would seem pretty definitely established that the conventional functions of the church have well-nigh completely evaporated in the light of contemporary knowledge and intellectual attitudes. It must be conceded that the theologian is no longer needed to chart out and control the supernatural world and supernatural powers, inasmuch as the existence of such entities can scarcely be established. It is equally apparent that the theologian can not by himself locate, describe or interpret the new cosmic God believed by some to be implied in the discoveries of modern science. Neither can the theologian supply detailed moral guidance in the way of indicating how man must live in order to achieve the maximum degree of happiness here on earth. Nor can the church support its ancient pretensions to guiding and controlling recreation or in supplying popular pageantry. This raises the important question as to what the church can legitimately engage upon in harmony with the tenets of an open-minded and contemporaneous secular attitude.

It would seem that the most reasonable field for the functioning of religion in contemporary society is in the way of providing for the mass organization of the group sentiment of mankind in support of the larger principles of kindliness, sympathy, right, justice, honesty and decency. Just what constitute the essentials of right and justice would have to be determined by the appropriate scientific and esthetic experts, but these experts have little potency in the way of arousing ardent popular support for their findings. Religion has thus far been the most powerful agency in arousing and directing the collective will of mankind. Therefore, we may probably contend with safety that the function of a liberalized religion, divested of its archaic supernaturalism, would be to serve as the public propaganda adjunct of social science and esthetics. The social sciences and esthetics would supply specific guidance as to what ought to be done, while religion would produce the motive power essential to the translation of abstract theory into practical action. There would, however, be ever present the problem of restraining this educational propaganda and keeping it in thorough conformity with the recommendations of science and art. The function of the church, then, would be to organize the mass mind and mass activities in such a fashion as to benefit secular society and not to please God, at least not as God has been understood and expounded in the orthodox religions of the past.

The writer is inclined to support this conception of the future and permanent function of the church, though there are some observers of high standing who declare that the secular lecture platform is more suitable and adequate, and that the public forum and the public schools must ultimately supplant the ecclesiastical edifice as the center of intelligent propaganda and the development of collective sentiment for social improvement.

It would appear to the writer that the problem is not so much one of the nobility or the validity of this function of religion or one of its value to society, but rather the question of whether or not the church can successfully carry out such a type of social service. The issue is primarily the one of whether an organization, hitherto almost exclusively devoted to the understanding, control and exploitation of the supernatural world, can be completely transformed into an organization for the purpose of increasing the secular happiness of mankind here on earth. Such a transformation would imply a complete revolution in the premises and activities of religion, and we have little or no evidence from the past to give us any definite as-

surance that so profound a transition is practicable or attainable. The issue is fundamentally whether organized religion can be held together and can operate without a sense of mystery and a fear of the unknown. The thrill from the mysterious has been the core of all past religion, and we have nothing to give any final assurance that religion can persist without this dominating element of mystery and fear. Certain writers contend that there will always remain a certain fringe of mystery, particularly in the way of unsolved scientific problems, as well as the general mystery inherent in the riddle of the universe. But, as Professor Shotwell has well indicated in his "Religious Revolution of Today," the mysteries of modern science are quite different in their premises, manifestations and psychic effects from the conventional religious mystery based upon an emotional reaction to a hypothetical supernatural world. The reaction to the mysteries of science does not promote that group-forming tendency which Ward, Hankins and others have shown to be so characteristic an effect and accompaniment of supernatural religion. Abstruse scientific perplexities and the riddle of the universe may promote advanced forms of cerebral effort but they are not likely to evoke a sentimental thrill or to generate a crusading passion in human assemblages. Indeed, some leading social scientists contend that the divergence between the old supernaturalism and the new secular program is so great that no real common ground can be found. Hence, they argue that we should not contaminate and confuse the new secular type of ethical enterprise by denominating it religion. This is certainly a consideration which is entitled to receive serious thought.

It is held by many that the majority of mankind will always remain essentially superstitious and victims of supernaturalism. While not optimistic with respect to the possibilities of rapid intellectual emancipation on the part of the majority of men, nevertheless, the writer questions seriously whether or not we may assume the indefinite prolongation of the domination of man by superstition and gross supernaturalism. Even the most benighted southern Baptist of to-day is almost secular in his daily life and attitudes as compared to the medieval peasant or the unconverted Indians of America though he may formally adhere to a primitive cult.

EVOLUTION AND RELIGION

By AUSTIN H. CLARK
U. S. NATIONAL MUSEUM

No question is of greater importance at the present day than that of the relation of science to religion. We in the United States are now definitely embarked on what in the years to come will be regarded as a type of culture new in the history of man, a culture chiefly characterized by the increasingly broad application of the correlated facts of science to our daily lives.

Many regard this type of culture now rapidly developing as wholly materialistic in its nature and as a growing menace to the non-material side of human life. They argue that by affording in rapidly increasing measure opportunities for recreation and for diversion it is correspondingly inimical to the more serious cultural and spiritual phases of human understanding.

But is this true? We are prone to judge conditions by the most obvious phenomena connected with them, by those phenomena which intrude themselves on our attention, either in our personal every-day experience or as supplied to us through magazines and newspapers. We are all too likely to forget that perhaps these are only superficial, transient and to us unwelcome attributes of a social readjustment.

History shows us that after all human nature has through the ages remained fundamentally unchanged. Outward appearances have undergone marked variations from one epoch to another, but as a rule these have affected only a small proportion of the people, or else have been wholly superficial.

Since the basis of the new conditions is the ever-increasing application of the facts of science to our material welfare, it is fitting that we should survey the present situation and from this survey ascertain so far as possible both what the present situation is and what the future has to offer.

One hears it commonly remarked that a firm belief in science eventually will supplant religion, or at least so modify it that it will be a wholly different thing from the religion that our fathers knew. One also hears it said that science and an increase in scientific knowledge eventually will be blocked by the growing opposition of religion.

Neither hypothesis is tenable. There can be no conflict between science and religion. For truth is truth quite regardless of the manner in which it may have been attained, whether through the paths of science or through religious teachings.

Through religion all of the very numerous factors, material and non-material, which in any way bear upon human existence, both individual and social, are coordinated. Religion contemplates order in all things, whether touching human affairs or not. But when subjected to analysis, everything is found to have a bearing more or less direct upon human activities and human welfare.

Through scientific investigation we are striving to discover and to correlate the facts which will enable us to understand the ultimate order upon which the universe, in the broadest application of that term, is based, and in addition we are endeavoring to find the means of applying such elements of this order as we are able to determine to human activities with a view to the betterment of human welfare.

Science, therefore, is engaged in building up a structure which should serve to strengthen the foundations of religion, not to weaken them.

Approaching the same end by different paths, the one material and the other

spiritual, there would seem to be no reason why science and religion should not go hand in hand, and, working together, hasten the mutual progress toward the common end.

But, like all things human, science on occasion becomes directed into paths that seem to run counter to religion. Perhaps the best example of such a manifestation at the present time is afforded by the concept which is known as evolution.

What is evolution? Evolution is commonly defined as a doctrine which assumes the gradual development step by step of all the widely varying forms of life from an original form of simple structure. While technically correct, this definition is somewhat misleading. It is obvious to every student of biology that there is a fundamental plan or system of some sort underlying the organic world, and further that the innumerable facts acquired through the study of biology can be properly evaluated only when they are considered in their true relation to this fundamental plan.

It happens that all the theories which have been proposed to explain the interrelationships of plants and animals have been based chiefly, largely, or at least in part, upon the history of plant and animal life as we have learned it from the detailed study of the strata in the rocks wherein are preserved the remains of the plants and animals of ages progressively more and more remote, or upon the development of the individual. It is obvious that the life in any single epoch must have been a continuation of the life of the epoch just preceding, and so on down to the earliest fossils that we know. Because of this time element which has entered into all the hypotheses which have been brought forward to explain the interrelationships of organic life, these have come to be known as theories of evolution.

None of these theories of evolution are in themselves antireligious. During the passage of the years, however, they have been altered and emended and have assumed a narrow, inflexible and dogmatic form which has been presented to the public not as a theory through the application of which the correlation of many isolated facts is rendered possible, but in the form of undebatable truths.

There can be no conflict between true evolution and religion. But dogmatic evolution, which demands the acceptance as established facts of many assumptions and hypotheses which are more than dubious has no place either in science or religion.

This idea was well expressed by Sir Oliver Lodge, who said, "Brilliantly true and successful in their own territory, they [the truths of materialism] are occasionally pushed by enthusiastic disciples over the frontier line into regions where they can do nothing but break down." He added that there is a tendency "to press the materialistic statements and scientific doctrines of a great man like Huxley, as if they were coextensive with all existence. This is not really a widening of the materialistic aspect of things, it is a cramping of everything else; it is an attempt to limit the universe to one of its aspects."

Professor Whitehead has expressed his view of the matter in a different but equally forceful presentation. He said that "Darwin's own writings are for all time a model of refusal to go beyond the direct evidence, and of careful retention of every possible hypothesis. But those virtues were not so conspicuous in his followers, and still less in his camp followers."

Just what is it that furnishes the basis for these remarks? This I shall illustrate by quotations from Professor Huxley's writings; but it might equally well be illustrated by comparable quotations from Darwin. Professor Huxley said that

it is clear that the result of the comparison of the Miocene and the present Faunæ is distinctly in favour of Evolution. Indeed I may

go further. I may say that the hypothesis of evolution explains the facts of Miocene, Pliocene and Recent distribution, and that no other supposition even pretends to account for them. It is, indeed, a conceivable supposition that every species of *Rhinoceros* and every species of *Hyæna*, in the long succession of forms between the Miocene and the present species, was separately constructed out of dust, or out of nothing, by supernatural power; but until I receive distinct evidence of the fact, I refuse to run the risk of insulting any sane man by supposing that he seriously holds such a notion.

Surely no one with any knowledge of biology can find the slightest reason for taking exception to this statement, while those with no knowledge of biology are in no position to refute it.

Had the matter rested here, the theory of evolution would not have met with any serious resistance. But no theory of evolution is tenable which does not consider the relationships of man.

On this point Linnaeus had long before remarked that he had been unable to detect any character by which a man could be distinguished from an orang. Smellie, in 1790, had written:[1]

In the chain of animals man is unquestionably the chief or capital link. . . . From him all the other links descend by almost imperceptible gradations . . . from man to the minutest animalcule. Man, in his lowest condition, is evidently linked, both in the form of his body and the capacity of his mind, to the large and small orang-outangs. From the orang-outangs and apes to the baboons the interval is hardly perceptible. The true apes have no tails and those of the baboons are very short. The monkeys, who form the next link, have long tails, and terminate this partial chain of imitative animals, which have such a detestable resemblance to the human frame and manners.

This is a clear and concise presentation, one hundred and forty years old, of the view-point of a dogmatic evolutionist.

Professor Huxley's treatment of the matter was characterized by strict adherence to the demonstrable facts. He wrote that " . . . whatever system of organs be studied, the comparison of their modifications in the ape series leads to one and the same results—that the structural differences which separate Man from the Gorilla and the Chimpanzee are not so great as those which separate the Gorilla from the lower apes." This is a statement of anatomical facts capable of indisputable proof. Huxley continued,

But in enunciating this important truth I must guard myself against a form of misunderstanding which is very prevalent. I find, in fact, that those who endeavor to teach what nature so clearly shows us in this matter, are liable to have their opinions garbled, until they seem to say that the structural differences between man and even the highest apes are small and insignificant. Let me take this opportunity then of distinctly asserting, on the contrary, that they are great and significant; that every bone of a Gorilla bears marks by which it might be distinguished from the corresponding bone of a man; and that, in the present creation at any rate, no intermediate link bridges over the gap between *Homo* and *Troglodytes*.

He also pointed out not less sharp, though somewhat narrower, lines of demarcation between the gorilla and the orang, and the orang and the gibbon, and noted the complete absence of any transitional forms between them.

While structurally the line of demarcation between man and the great apes, though sharp and distinct, is not so very broad, there are other things to be considered.

Huxley insisted, and rightly, on the structural similarity, which is indeed capable of conclusive demonstration. But he said that "At the same time no one is more strongly convinced than I am of the vastness of the gulf between civilized man and the brutes; or is more certain that, whether *from* them or not, he is assuredly not *of* them." He said further that

Our reverence for the nobility of manhood will not be lessened by the knowledge that Man is, in substance and in structure, one with the

[1] Quoted from Frederic T. Lewis, *Boston Medical and Surgical Journal*, vol. 191, No. 10, September 4, 1924, p. 431.

brutes; for, he alone possesses the marvellous endowment of intelligible and rational speech, whereby, in the secular period of his existence, he has slowly accumulated and organized the experience which is almost wholly lost with the cessation of every individual life in other animals; so that now he stands raised upon it as on a mountain top, far above the level of his humble fellows, and transfigured from his grosser nature by reflecting, here and there, a ray from the infinite source of truth.

Huxley might have added to the possession of rational articulate speech certain other attributes common to all races of men but not found in any of the apes or other mammals.

Perhaps the most interesting of these is the use of fire, which is universal among the races of mankind, as far back in geological history as we have any trace of human remains. Not less interesting is the use of tools, which is also universal. Then there is the wearing of clothes and ornaments, which may be reduced to a minimum but which is invariably present in some form or other in every race of which we have historical knowledge.

But from the non-material standpoint by far the most significant difference between man and the apes is the existence in man of a socially effective sentiment of love resulting in a family life and therefore in conditions wholly different from the promiscuous horde life common, so far as we know, to all the monkeys. Among the monkeys each female is capable of raising her own young, but the raising of a human family requires the ministration of both parents.

Much has been written on the comparison of the sexual life of apes and man, and it has been argued that the family life of man gradually developed from the promiscuous relations of the apes.

But the fact that in man the female is incapable of raising a family without assistance and the existence in all human races of taboos and laws directed toward the maintenance of the family would seem to show that family life was from the first a fundamental human institution. Laws and taboos are not, so far as we know, invented to mold society into a new and preconceived form, but on the contrary to correct the evils recognized as possessing disruptive or destructive tendencies which from time to time appear.

Regarding the fossil history of man, although much has been learned in recent years still no fossil remains have as yet been found which are indisputably those of a missing link. Several such missing links have been described, but all of these have been redetermined by competent authorities as either man or ape or as based on a combination of the remains of both man and ape.

Summing up what has just been said, we must admit the anatomical evidence of the relatively close physical structure of man and the great apes. At the same time we must admit that there exist important and clean-cut differences between them. Further, we must admit that above and beyond mere physical differences man is a being of a nature wholly different from that of any of the apes. Lastly, we must admit that no indubitable "missing links" connecting man and apes ever have been found.

It is apparently incontestable that man is separated by an important gulf from all the man-like monkeys. How can this fact be harmonized with the general evolutionary plan which is so evident as we trace the various types of mammals of the present day back through progressively earlier and earlier epochs to their first appearance in the rocks?

None of these evolutionary lines are quite continuous, for in them there are always breaks or gaps—though often very slight—between successive types and between collateral lines. But in general the lines, so far as the vertebrates are concerned, are obvious, clearly marked and undeniable. The gaps and breaks are to be explained by an application of knowledge gained through the study of mutations and of variation.

We can not deny the actuality of the existence of these gaps, and therefore must admit the lack of perfect continuity in every evolutionary line.

If we assume that the occurrence of the gaps is due to more or less broad and sudden variation or mutation, a phenomenon abundantly in evidence at the present day, then we must entertain the supposition that evolution has not ceased to operate, but is still in progress at the present time.

Between the several groups of sea invertebrates the lines of demarcation are so very broad that it is not possible to arrange these in any sort of evolutionary line. But they seem to fit perfectly well into a geometrical figure (*Journ. Washington Acad. Sci.*, vol. 13, No. 7, April 4, 1923, pp. 129–138) in which each is shown to have affinities with several others, not merely with a single one.

I mention this in order to explain the attitude toward evolution of Professor Louis Agassiz. Toward the Darwinian hypothesis Professor Agassiz always maintained a determined opposition. I believe that this was due to his interest in and very intimate acquaintance with the animals of the sea which certainly can not be made to fit into any scheme predicated on the interrelationships which are found among the vertebrates.

From a perusal of the paragraphs preceding it is clear that in the minds of reasonable people there can be no conflict between evolution and religion. A definite plan and order underlies the entire animal kingdom which thereby is susceptible of interpretation as a unified entity. Evolution has not spent itself, but is still an active force, though whither it is leading we can not even guess. Man is not an ape, and we have no evidence that he ever was.

Personally I am wholly engaged in describing and interpreting the facts of science. Yet I am thoroughly aware that a world expressed entirely in terms of scientific laws and formulae would be an impossible place in which to live. Humanity requires something in addition to the cold logic of ascertained facts and proven theories. Both religion and philosophy are essential factors when it comes to human welfare.

Along these lines Professor Huxley said, "It is worth any amount of trouble to . . . know by one's own knowledge the great truth . . . that the honest and rigorous following up of the argument which leads us to 'materialism' inevitably carries us beyond it"; and further

> If the materialist affirms that the universe and all its phenomena are resolvable into matter and motion, Berkeley replies, "True; but what you call matter and motion are known to us only as forms of consciousness; their being is to be conceived or known; and the existence of a state of consciousness apart from a thinking mind is a contradiction in terms."
>
> I conceive that this reasoning is irrefragable. And, therefore, if I were obliged to choose between absolute materialism and absolute idealism, I should feel compelled to accept the latter alternative.

Professor Whitehead has significantly and truly said, "When we consider what religion is for mankind, and what science is, it is no exaggeration to say that the future course of history depends upon the decision of this generation as to the relations between them."

PERSONALLY CONDUCTED

By Professor NEVIN M. FENNEMAN
DEPARTMENT OF GEOLOGY, UNIVERSITY OF CINCINNATI

MOST of us have traveled. Most of us at some time or other have worried over tickets and baggage and passports and the choice of hotels and strange regulations unknown at home, all made worse by inability to converse in a strange language. Most of us at some time or other have been tired, tired planning, tired dealing with strangers, tired of going, tired of seeing things, tired of everlastingly having new experiences, tired of effort, tired of responsibility. We wanted to be back home, back to something familiar, back to routine, back to the life that did not demand incessant initiative.

Some of us have tried traveling without initiative, traveling in the passive voice, as it were, without planning, without deciding things, without looking forward or backward, sometimes not even looking around very much, personally conducted, hiring some one else to get us traveled. We wanted to get things and places checked off; wanted to say we had been there; wanted the credit that comes from going through the motions. We might even "fake" a church or two, or a famous painting, pretending to have seen them when we had not. A few more or less made no difference to us; the guide may have failed to point them out, and the fault was not ours, so we deserved the credit and had the right to check them off.

Now these two methods of travel, the one in the active voice, the other in the passive, are a parable intended to shed light on our systems of education. American colleges have chosen the second way, the way of the "personally conducted." Its advantages are obvious.

In the first place, more people are willing to take it that way. There are many young people who really have no objections to being educated if only they don't have to worry while it's going on. They have no thirst for knowledge; in fact, it rather bores them. To start out after it alone would be the last thing in the world they would think of, but if there's a good crowd and some one else will do the head-work, selecting the bare minimum of facts to be learned and tell them each day what to do next, they are willing to submit. Anyway it takes very little of one's time, and meantime they are having a good time in other ways. So it's plain that the personally conducted college course has the advantage of appealing to large numbers.

In the second place, it lends itself to organization and quantity production. Fifty students with a thirst for knowledge and a tendency to think, and all raising questions of their own—What could a man do with such a bunch? It is easier to take a hundred, or two hundred, and say: I will tell you what you ought to learn and how to learn it, and when you have enough; and I will make your daily programs and tell you what to think. With such a system well operated there are few troublesome questions.

In the third place, the system favors standardization and makes certification easy. This is the real nub of the argument. Many employers now demand young men with certified educations. Suppose that in order to hold certain positions it were necessary that a man should have traveled. How would it be possible to tell the man who had traveled from the man who had not? It might require half an hour of conversation, or in some cases a whole hour, to determine whether a man had the kind

of culture that comes from travel. It is far simpler to demand his certificate, wherein the guide sets forth—This is to certify that Mr. G. Trotter was a member of my party from such a date to such a date, that he was actually present at the following places (here follows the list); that to my certain knowledge he entered bodily into the British Museum, the Vatican Galleries, the Louvre and fifty-seven other museums and galleries, to wit: (here follows the list); that the days and hours on which he absented himself from the prescribed itinerary did not exceed 10 per cent. of the whole; that he stopped at no hotels not authorized by the management, and that he ate all the meals stipulated except as herein enumerated, and that for the entire tour he is entitled to a grade of C plus. Of course with the itinerary once standardized a simple diploma in Latin might be substituted for a lengthy recital of facts. Such a diploma would at once distinguish the man who had really traveled from the man who had merely gone through Europe to observe, learn and enjoy on his own account.

It is the same way in college education. A man's diploma shows that his bodily presence has been actually accounted for during 90 per cent. of the hours named on a certain schedule for four years; that he has gone through certain motions in laboratories where his presence was required; that he has read certain books in a certain order, dividing up this reading into daily rations as prescribed by the proper authority; that not more than 50 per cent. of the mental work of the curriculum has been substituted by football, basketball, swimming, pitching horseshoes, amateur theatricals and service at the polls in the interest of bond issues.

The argument is urged with some force that the personally conducted college course prevents failures, discouragements, waste of effort and suicide. In European universities, where students are supposed to want knowledge and are treated accordingly, the mortality is notoriously high. Among the crowds that come to college there are many who have not the interest or ambition or moral fiber to work from day to day unless held to their tasks by a constant checking up. There can be no doubt that a system of pedagogic surveillance brings some such to accept a minimum of knowledge who would otherwise fall hopelessly behind and be eliminated. Others are wholly unable to acquire even the modicum demanded by our colleges without daily help. Americans have a profound prejudice against natural selection. There is a widespread feeling that if the student is not actually feeble-minded, commits no grave crimes and pays his tuition, the college is in a manner morally obligated to see that he gets an education.

This prejudice against natural selection is closely related to another consideration, namely, that the personally conducted college is democratic. It obscures the natural differences among men. By meting out a daily ration and spending most of the time checking up, we hobble the man who might otherwise run and drag the man who is unable to march. Thus the whole company is kept together and one man is as good as another. From a distance the company looks imposing and makes us feel like singing "Like a mighty army moves the church of God." It's only when we get up close and look at individuals that we see that neither the best nor the worst are doing what God made them for.

It is a well-known fact that American practice in higher education differs radically from that of Europe. America treats the student as a child; Europe treats him as a man. We decline to assume that his desire for knowledge is real and dominant. We watch him at every turn, check his attendance at

every class hour, assign him daily tasks, test him at short intervals to make sure that he works, tell him whether and when and how and how much to play football, decide when he needs help and press it upon him. The professor, instead of devoting himself to those who can and will, spends most of his time on those who either can't or won't. Rather than see students exposed to heresy we turn the lights out.

In Europe the student is taken at his word as a seeker after knowledge. He is given opportunity instead of surveillance. Often the assumption is wrong, the confidence misplaced and the opportunity scouted. The percentage of failures is high. None the less the man who can and will is saved, and freed from the drag which our lockstep system imposes. The European system frankly avows that men are not born equal. As for freedom, the European university is the freest place on earth, but it is not democratic except in opportunity. The American university clings to equality, which it insures by the sacrifice of freedom and by systematized mediocrity. It is inherent in our system of personally conducted education that the distinction between able and unable, zealous and careless, is obscured. Thus we parade our democracy like a watch in a gold case, while leaving out the mainspring, individual responsibility.

Our squeamishness at natural selection in the educational field is curiously out of harmony with the philosophy of individualism which still dominates our ideas in the commercial and professional world. America still admires a Henry Ford and worships a Lincoln and does not squirm at the thought that their competitors with equally good intentions received less reward.

Equally is our management of higher education out of harmony with our vaunted admiration for sportsmanship. Theoretically, we like a man who plays the game and asks no odds and does not squeal when hurt. Practically, we prefer to debase the university system rather than permit the incompetent and listless to bear the penalties of their limitations or faults.

The effects of this system might be borne with equanimity so far as they concern the unable and the unwilling. It is in the sacrifice of the able and willing that the injury becomes deplorable. The student is generally a grown man. The ostensible reason for his presence in a class is the desire for intellectual attainment. The ostensible task of the instructor is to cooperate with the student in his efforts. The ultimate responsibility is on the student. With such a relation, there is no need for surveillance, coddling, threats and everlasting admonition. These things become necessary only when the motive of intellectual attainment becomes subordinate to other motives. Then, according to the American system, responsibility passes to the instructor whose duty it is to furnish substitute motives and "get the class through." Such motives take the form of fear and hope of grades and credits based on compulsory tasks closely supervised and stimulated by constant prodding and threats in the form of tests. Generally a charge account is opened, with assignments on one side and grades on the other, and there is a regular system of bookkeeping by which the student may know from time to time whether his balance is in red or black. Much of the instructor's time is spent in getting red balances into black. The disproportionate amount of interest devoted to this borderland where red meets black affects the character of the instruction and withdraws attention from the real students whose solvency is beyond doubt.

Necessarily the relationship between student and professor under such a system is wholly different from that which

prevails where the professor's first concern is to cooperate with those who are seeking knowledge. The inspiration of companionship is lost and even those students who are capable of better things accept the situation and come to look upon the state of their charge account as the thing that matters most.

The damage to the better student is twofold, and great on both counts. First, his scholarship is limited and, second, he fails to acquire that intellectual sincerity which is fundamental to independent work and leadership. If the university fails to develop intellectual leadership there is poor satisfaction in a long roster of lame ducks who have been nursed and coddled and threatened and driven and dragged along just far enough to save the institution's face, and then turned out to begin work, as they should have done four years earlier.

PROGRESS

By WILSON D. WALLIS
UNIVERSITY OF MINNESOTA

THE word "progress" was first used in the modern sense by Lucretius, a Roman writer of the first century B. C. It means literally "going ahead," its contrary being "retrogression," "going backward."

Lucretius believed that the evolution of human society exemplified progress, although he recognized that some of the changes which successive centuries had witnessed were not improvement. Considering social evolution in its broad sweep, he says in effect, man has made progress, but here and there he has retrogressed, or has stagnated, rather than progressed.

Though no comparable view of evolutionary progress is found in the civilizations which antedate Lucretius, most of them had a concept of progress. They believed the highest good had been realized in the earliest stages of man's life, in the paradise or elysium in which men lived before they embarked upon social and political evolution. They therefore viewed the reattainment of an earlier status as progress. A harking back to an earlier status was, to be sure, retrogression in the sense that it was a retracing of a course traversed in pain and sorrow, but it was progress, so at least they thought, in the sense that it was the way to attainment of the better life. Thus even those writers who bemoan the passing of better times have a concept of progress, otherwise they could not depict man as degenerating.

Contemporaries have attached various meanings to progress. To some it means merely the continuation of processes already under way. The term as used by them may connote mere continuance of a movement, force or activity, or merely an increase in the momentum of a phase of social life.

Thus a nation is said to make progress in manufacturing, road-building, imperialism, and so on, when these activities are carried on with increasing zest and success. But this concept is too narrow, for quantitative or linear dimensions can not measure progress. Many a town or city boasts of "progress" in population, meaning that the number of inhabitants is increasing; but whether the increase in number of inhabitants really indicates progress depends upon various conditions.

Or one says that a community makes progress in wealth, meaning that the valuation of taxable property or of bank clearings is increasing; but this too must be interpreted in human terms before one can ascertain whether it indicates progress. A mere quantitative increase is as such a mere quantitative

increase, and it does not necessarily indicate progress. If men are no better off there is no progress, there are merely more men who are no better off; and if dollars increase but human weal is no greater because of human wealth, then, too, there is no progress.

Others use the term "progress" to indicate approach toward a goal, explicit or implicit. In any helpful sense of the term, no doubt progress implies a goal, and, indeed, something more than a mere goal. A disease may be said to be moving toward a goal, but to the extent that it is attaining its culmination the patient is not making, but is failing to make progress; the patient is making progress if he is thwarting the disease. Progress, then, implies at least a desirable goal and this means more than merely a desired one. It means a goal which embodies a desirable end and one which, in the long run, brings satisfaction. A desirable goal, therefore, presupposes a choice of goals, a choice made with discrimination and a knowledge of means as well as ends, and choice, in turn, involves evaluation. There must be also a weighing of means, for in choosing the goal one is also choosing the means to it; and when a man or a culture chooses wrongly, "life and the consequences of the wrong may not ask as to intent," but merely demand the penalty.

Progress, then, implies choice of a desirable goal and of adequate means for attaining it; and the highest progress involves the choice of the most desirable goal and the best means of attaining it. But interpretations of conditions underlying progress have varied widely.

Some have regarded progress as resting in the hands of fate, destiny or inevitable historical forces. Everywhere, it has been said, man struggles with nature, and in every culture he desires to improve his lot.

Even in the remotest periods of prehistory there was a struggle for the conquest of nature and for the accumulation of goods. Early Stone Age man improved the crude stone implements of predecessors, and each generation, or at least each millennium, added something to the achievements of predecessors. Thus, without knowing it, he who struggled with circumstance helped to bring the modern age.

Retrogressions also are regarded by some as inevitable. Man may struggle, but he does not always plan wisely or execute efficiently. But though setbacks are real, they are temporary and should not occasion discouragement.

Given things as they were, we are assured, events could not have been otherwise, and men could not have acted differently. We may admire the torchbearers of the Renaissance, but granted the opportunity, the response to the inspiration was inevitable. The Industrial Revolution might have come earlier or later, but come it must; and given things as they were a century ago, a Civil War in this country was inevitable. The World War, similarly, grew out of antecedent conditions; it might have come earlier or later, but come it must.

With regard to the invention of mechanical devices a similar conclusion is drawn. But for a happy concourse of events and personalities the radio might not have been invented for another decade, but invented it would be, once man had advanced to a certain point in science and ambition. Thus inventions, we are told, are inevitable, once culture has attained a certain status of accumulated science and technology.

In support of this position attention is called to the fact that certain discoveries and inventions can be predicted with a slight margin of error. Perhaps there is no general progress, but only progress in certain fields of activity. However that may be, progress in one line is not an isolated phenomenon, but implies progress in related lines.

Progress in technology, for example, has been preceded, accompanied and fol-

lowed by progress in trade, science, specialization, and an assured, that is, a dependable interdependence, without which any considerable specialization is impossible. Thus the Industrial Revolution has been intimately bound up with advance in trade, science, technology, a credit system and internationalism, and advance in any one of these was always to some extent dependent upon advance in the others. Hence social progress, however strictly interpreted, involves progress in some larger sense, as, for example, in political life; and this in turn is bound up with economic and industrial organization, technological development and with communication and the dissemination of information. A change in any one of these may have far-reaching effects in the social world, as witness events which followed the development of the printing-press, the railroad, the telephone, the telegraph, the radio, the aeroplane. Thus the problem of progress is many-sided, and it becomes increasingly difficult to fathom as civilization becomes more complex. Social life, for example, is a phase of a specific civilization, and it is therefore dependent upon a specific culture. But, as history testifies, civilizations rise and fall. Must, then, every civilization, after a certain period of development, fall and pass off the stage?

If such be the case, what limits does this necessity impose upon the possibilities of social progress? In addition to the apparently limited life of a civilization, there may be within a given civilization certain specific limitations upon progress. Greek civilization, for example, seemed capable of making great progress in literature and the fine arts, but it was weak in national and international politics, and in the domain of technology; and perhaps it was destined to make no notable achievements in other domains. Another possible limitation upon progress arises from the fact, if fact it be, that along with the seeds of good are sown the seeds of evil, so that in any culture which is advancing there is a contest between the forces which make for progress and those which tend to thwart it. Witness the increase in crime, disease and war which have been the invariable accompaniments of progress.

A primitive culture is comparatively free from these untoward tendencies, but a developing civilization must cope with them at every step. If these are necessary evils, then, it seems, a bane is inherent in progress. Indeed, perhaps progress is necessarily dangerous.

Consider, for example, the development of transportation. With canoe and the dug-out there are few dangers; the sailboat is a step in advance, but it brings added dangers, and the steamboat intensifies these in a thousand ways—think of the *Titanic*. In the ox-cart we travel slowly but safely; in the horse-drawn vehicle we make more rapid progress but encounter greater dangers from steed and speed; in the automobile we hurl our bodies through space with locomotive velocity, and there is some danger of hurling them straight to heaven or hell; in the aeroplane we fly faster than the swiftest birds, but the danger from a somersault or a nose-spin is greater than the danger from a hurtling automobile.

Do these dangers typify a tendency which is inherent in progress? Certainly they seem to be an accompaniment of many phases of it.

Internationalism has grown, but it has brought a larger number of possible and perhaps of actual entanglements. The larger the number of nations with which we have relations, the greater the possibilities of friction and enmity. Meanwhile war itself becomes fraught with greater danger to all participants.

In using instrumentalities we become dependent upon them and to that extent

place our fate beyond our immediate control. The Erewhonians discovered this danger and they therefore rigorously excluded all machines from their civilization. Is there not a grain of realistic truth in this ironic fancy of Samuel Butler? Are we not annually more dependent upon our machines? And is it not true that we work for them as well as they for us?

Finally, there is the possibility that a civilization, particularly our civilization, may become too complex to cope with the resulting problems. With all our boasted ingenuity and science we are almost fundamentally ignorant of the character of our civilization and of its trends. Although human presumption knows few bounds, no one presumes to understand contemporary civilization. At most, one claims but small knowledge of a small field. We do not know where we are going; neither do we know that we are on our way. If there is a desirable goal somewhere in the future, then we may be far out of our way.

We have given tremendous impetus to our culture and have specialized and intensified it in many ways; now our problem is to keep up with it, and little time is left us to inquire whither it leads. Nor can one be confident that the most leisurely inquiry would make us much the wiser, for the course of culture is difficult to predict. The goal, if there is one, seems to be somewhere the other side of nowhere.

THE KING OF MUSICAL INSTRUMENTS

By Professor ARLAND D. WEEKS

NORTH DAKOTA COLLEGE, FARGO

WHILE no violin census has ever been taken, the number of these instruments in existence is immense; the realm of the violin is wide. Unlike the automobile, which, produced by the million, goes into the discard by the million when used for a brief span of years, a violin is cherished the more tenderly with each passing year, mileage increases its value, and century-old models top the market. Tens of thousands of violins are imported into the United States of America annually, at a tariff of one dollar each and 35 per cent. ad valorem, and factories and individual workshops within our borders add to a yearly output as nearly approximating immortality as any object of commerce knows. Ships become obsolete; fine furs are ravaged by moths, faded by the sun, worn by rubbing against show cases; garments go out of style; the gold watch grandfather handed down is replaced by a thin one. Change and decay is all around—except in violins.

Death rarely comes to the violin. Have you ever heard of a violin being thrown away? Search the ash cans and dumps of our cities, and not one. Occasionally, to be sure, a fatality occurs, as when a player in an orchestra has his violin collapse in his hands, or when a fire destroys, as in the instance of the Stradivarius left in his room by a young man near Lake George some forty years ago, and known to have perished in the flames that consumed the residence a few hours later. Moisture may cause a violin to fall apart, while intense heat may damage beyond repair. Some may be lost, crushed or abandoned, often needlessly, as not capable of restoration. But authentic cases of the passing of violins are few and far between. Old age is coveted by the king of instruments, and the teeming realm adds numbers yearly, nay, hourly, a fact that implies a stress for a place in the sun. Will not the world become overpopulated with violins? It is inconceivable that the new violin, from the violin-making centers of France, Germany, Austria, England, and from individual producers in the United States in cities and villages—Atlanta, Minne-

apolis, Duluth, New Orleans, Cincinnati, Grand Rapids, Scranton and Coffeyville, Kansas—should not encounter a sales resistance and a toxic condition of the marketplace from the sheer weight of numbers. The instalment plan of selling the king of instruments, in effect with the leading music houses, bears testimony to the stress. No human population can advance at the rate of augmentation possible with a musical instrument that lasts practically forever.

Among the stresses and strains (not musical), which threaten less than peace in a supposedly harmonious realm are those of the new versus the old makers. The shops of the makers of one, two or three centuries ago in Italy and mid-Europe were as filling stations in the suburbs for numbers. There were great master makers, the Guarneri, Stradivari, the Guadagnini tribe, the Amati family, Bergonzi, Storioni, Maggini, the Gaglianos, Montagnana, Tononi, and scores of other well-known names, and in addition, the ubiquitous amateur. The old makers acquired a reputation for the production of beautiful and pleasing instruments. Cremona, northern Italian city where violin-making reached its climax by the middle of the eighteenth century, became as it were a sacred city, and where Stradivari once sold his best violins for twenty-five dollars the violin-crazed tourist pauses with bated breath. The old makers gained an enviable reputation in their own day; they have a marvelous reputation in our day. But whether such high repute to-day is based on musical values wholly or partly on tone and partly on zest for antiques is another matter.

The makers of new instruments today—and let us remind ourselves that the Cremonese violin was once new—claim that the modern-made violin, of the best type, is fully the equal of the old instruments. They say that the violin-using world must come to the use of the new violins: that the old ones are becoming weak and worn, that the fibers are losing their power to vibrate, going dead in the players' hands. The famous Cremona tone is declared to be sweet but weak. Tales are told of players with expensive old instruments who are compelled to exchange them for powerful modern instruments in order to hold their positions as musicians. Moreover, probably a heavy majority of all old instruments have been repaired or reinforced to make them more suitable for modern use. In the time of Stradivari playing in positions was unknown and the violins were tuned low. The necks of the old instruments must be lengthened for use to-day, and few of the instruments can be used without strengthening parts, especially the top plate. Ninety-five out of every hundred of the Stradivari violins, of which hundreds exist, carry reinforcements of patches and glue cunningly placed within.

The first struggle within the peaceful empire of the monarch was for power, and the palm for that goes to the modern violin. Charles Reade, the novelist, eminent judge of old violins, writing sixty years ago, said, "At present there are more scientific and intelligent Fiddle Makers than ever existed at Cremona." Reade gave the Cremona an advantage in sweetness, oiliness, crispness and volume of tone as distinct from loudness, but awarded the modern instrument superiority in power. Since Reade's day there are modern makers who claim the tone distinction of the old instruments together with power. Played behind a screen in a western city a master instrument of Joseph Guarnerius del Jesu and a violin by a local maker left an expert in doubt as to which was the priceless Cremona and which the handiwork of an American maker, below whose shop motor buses and street traffic roared. The chief of makers was the grand old man Antonio Stradivari (1644–1737), who produced by his own hands the wealth of a multimillionaire.

Disconcerting is it to find Ole Bull saying of the Stradivari violin: "But although the tone is wonderfully even and full, it is tinctured with a peculiar nasal quality. For this reason, though I have owned several fine specimens of this maker, among them one of the quartette made for the court of Spain, I have never played on them in public."

The layman would think it an easy assignment to find out whether the old Italian instruments are actually superior to the best of modern make. Let a word be breathed in confidence into the reader's ear: there is no field of human activity—not even in the rich and hoary institutions of religious tradition and sentiment—in which there is less of the strict ascertainments of science than in the violin world. Let one set out to glean the facts of comparison and he will return almost empty-handed, but he will have plenty of impressionistic views. Suggestion runs riot in violin land, where tone is heard by the eye, and acoustical properties are reflected by labels. Word came from the University of Iowa of tests of violins. By resonators is found—what? That good violins are better than poor ones; but nothing to help resolve the problem of comparisons of the new with the old. If one would have the truth about the old and the new he must needs proceed with full care to exclude suggestion, capturing the elusive fact, perhaps in the sieves of acoustical laboratories; only the world would then be the poorer through having lost a rich province of romance. Great artists use great old violins. Well, perhaps the audiences expect it, and again, do they always use them?

But as to appearance, the internecine strife between the new and the old varnishes is reported as definitely in favor of the old, with, however, here and there an announced contender in fighting mood. Connoisseur Reade, the onetime premier expert of England on Cremona violins, gave the case entirely in favor of the old varnishes; this after daubing varnish himself for years. The art of glorious varnishing rose, and fell. Before the year 1800 the divine fires of the varnish of the Cremonese makers, and of old Jacob Stainer, who also knew his varnish, had passed. Spirit varnish, stiff with resin, made its stultifying appearance. The varnish mystery of Cremona is still a mystery; the air is filled with conjectural explanations, skepticisms, counterclaims and present-hour assertions of formulas as good. It is all a maze. But who knows but that the antiquarian of three hundred years hence may rave over to-day's violin, sprayed with Lako-Duke, as the ne plus ultra of finishes? But let us be reverent. The writer for one, however, is free to confess that he, until he knows something about what others think beautiful, is a shade uncertain himself. Let the ancients and moderns continue if they must the fight of the formulas for the ideal appearance of the violin exterior. In one phase of the general strife victory may at once be accorded to the old—there can never be any more violins made at a time now long passed. The supply is limited. Once an old violin, always an old violin, whatever the tone, whatever the varnish.

But sometimes a new violin is also an old specimen; its label says so. Oh, had there been a pure food and drugs act in force upon the violin-makers who promptly saw a commercial advantage in labeling with distinguished names, flooding the world with misbranded, short weight and adulterated products! Not only were the names of distinguished makers pasted in the interiors of terrible fiddles, but the names of even minor makers were profusely plundered. Makers like Friedrich August Glass and Hopf (any one of the Hopfs will do) were made to lend their names to handicraft that left much to be desired in tone, model, outline, varnish, sound holes, purfling, bass bar, corner blocks,

scroll, finger board and graduations. Trade probably is not acquainted with a more extensive sweep of deception and false labels than appeared in the making of violins. Unquestionably, millions have believed that they had a genuine specimen of a maker when such they had not. It is evident that the genuine violins of the old makers were limited in number; but under the guilefulness of past years this number was made to appear hundreds of times as large. Ah, the struggle between the true and the false in violins has been, still is and ever shall be. Sad scenes too. David Laurie, canny Scot connoisseur of violins de luxe, tells of a refined and elderly Frenchman who fell sick and died soon after being convinced that an estimable violin, long in the family and believed to be a genuine Stradivarius, was not that master workman's product. At least one man traded a farm for a Stradivarius, by name; value, as adjudged by Chicago musical instrument intuition, eighty-five dollars. In Spokane, after pursuit across the country, was found a "Stradivarius" which had been included in a state's exhibit at the St. Louis Exposition; behold, a commercial violin of mean workmanship, darkened with seamy varnish and not even old. But probably thousands had paid this flimsy fraud the tribute of awe-tinctured gaze. The other day a newspaper reported the existence of a Stradivarius in a proud owner's possession, the instrument bearing the date of 1600, or forty-four years before the birth of its putative maker. The printing of labels must at one time in violin history nearly have equaled in extent the violin industry itself. It would be a gain if a few hundred thousand worthless old fiddles could be collected and used for parts and for kindling wood. Then modern makers would have a wider market, the old master makers could lie still in their graves and the public would be spared an amount of anguish from catgut and wire ill assorted with a sounding box.

One can not fail to sympathize with the regal instrument in its load of responsibility for keeping itself regal. Low-born specimens, variants from the ideal prototypes, are many and obtrusive. God never made so many different woods and qualities of materials as there are different kinds and qualities of violins made out of the trees. Human skill and lack of it have a way of transforming materials into a wonderfully wide range of excellence. No two violins, even by the same hand, are quite alike. The master makers were always trying to better their work; they presumably became tired of doing exactly the same things, and introduced variations of edges, corners, bouts and arching. No two violins on the face of the earth are precisely alike in sound, in which respect they are like people's voices. Did you ever hear two persons who spoke exactly alike? And one recognizes in a person after years have passed, after change of place, after sickness or misfortune, individual qualities of voice; so with violins. The bridge may be lowered and the sound post reset, the angle of the finger board may be altered and even the violin's insides may be modified, yet the tone is likely to be recognized as the one belonging to the instrument in its unregenerate or original state. The writer recently examined two instruments of a well-known American maker; they were as alike in appearance as two peas; their dimensions were exactly the same: thirteen and fifteen sixteenths inches long; same height of sides, same arching, same width of bouts, same everything. Heard together one could be distinguished from the other; there was a close similarity of tone, but one had a slightly fuller tone and more volume in the lower strings. With seventy parts, each of

which may vary infinitesimally in size, density, quality of wood, and with adjustments differing at least minutely of bridge, sound post and strings, with varnish perhaps not always from the same kettle, is it any wonder that many as violins are they are never twice wholly the same? Only a mathematician could calculate how many permutations and combinations of sound qualities would be possible through differences among seventy parts. Violins will be twice alike when two human beings are.

Beyond congruous and casual variations of construction lie avowed differences of practice among makers and of opinion among bystanders. By design sound holes are varyingly spaced, the length and proportion of parts established and thicknesses of wood caused to vary. Take a violin to an expert and he may thumb the top plate and say the graduations are too thin, while his brother expert may thumb the back and declare an unhygienic thinness appears there; another shakes his head over the non-symmetry of the veining of the spruce of the top, and still another eyes askance a bass bar not of uniform depth throughout its length. The amateur, depressed, may learn that he has overprized his violin, that not all the instruments made by good makers are good and that fine instruments have been ruined by attempts at improvement on the part of unskilled repairers. For peace of mind the owner should be chary of confidences, for here suspicion may be cast on the impeccability of one's violin, or one may encounter coldness in the man set on a different model. While disagreements may not amount to riot or insurrection, yet the hubbub of unlikemindedness is bound to unsettle the sensitive and disturb any who have not achieved the peace of dogmatism.

The king of instruments is scheduled for some disharmony with the sound physicist, who says the violin is almost an accident and could really be greatly improved if Fordlike intelligence started in that direction; who calls attention to the wolf notes, and to the different qualities of open and of stopped strings, and declares that the instrument is inexcusably weak as a sound producer; who says the effect of the mute on tone reveals that the bridge is pretty nearly the whole show (as if the effect of a flat tire goes to prove that with automobiles tires are pretty nearly the whole show). The early violin makers, we are told, were merely experimenters and rule-of-thumb workers, governed not by principles of sound production but largely by a mechanical opportunism. Thus, the incurving of the middle bouts is a necessity for the play of the bow, and what does it have to do with ideal sound production? The violin has been fitted to the player's convenience, its evolution as a sound box being thus limited. And if varnish is good for the outside, why not for the inside of the instrument? Give the acoustical engineer resources and commission him to improve the violin, and the time-honored canons of the luthier's art will go by the board, so is it said. To be sure, it *is* surprising that while epoch-making advance is made in surgery, architecture, costuming, sound transmission, seismography and heating plants, the most proficient violin-makers of to-day merely imitate craftsmen of two centuries ago. In what other field of human endeavor did early craftsmen command an ultimate science? There is not a violin house in the world that does not advertise imitations of this, that or the other violin masterpiece of two or three centuries ago. It may be all right, but——. The violin changes less than theology.

But on the whole the rule of the king seems fairly well assured. Lately tens of thousands of high-school pupils have taken to the violin as it is, in school orchestras. In the cliff-locked depths of the Canadian Rockies one descries at a distant cabin door a sprawling specimen

of humanity, a young male, holding a violin of light yellow hue on his right knee. In candle light in the rude homes of "our contemporary ancestors" of the Kentucky mountains young men play fiddles while others tap rhythmically on the fiddle body with a neat little stick of pencil size. The bush farmer of northern Minnesota "takes a tune" out of his violin while the blasts of December howl and the coyote yells. The king stands well in the hearts of his subjects, and none of his compeers can win such tributes as that paid to the violin when the playing of it brings tears to the eyes of the one who plays.

It can scarcely be expected, with thrones tumbling in an age of ruthless realism, that the long and heretofore essentially peaceful rule of the king of instruments will forever stand immune to the leveling tendency, which might take the form of a moderation of language of adoration. A pronounced rhetorical stress appears as between the exalted and perfervid terminology of ecstatic devotion and the sordid vocabulary of reference of those animated by irritation or by prejudice of the violin's occasional low associations. Even the prince of fanciers, the great Reade himself, did, in his "Petition to the Lords of the Treasury," in which he sought a lower dutiable valuation on his Italian violins, refer to the sacred substance of these as "carcasses," the instruments imported being more or less in a knocked-down form. The word *fiddle* is no such word as *violin,* the latter one of the handsomest words in English. If Nero fiddled when Rome burned—derision and hardness; if he played the violin—sublime poignancy! Any one inured to the rainbow vocabulary of real estate promotions and of complexion specialties might come unscathed through the literature of the violin, including the catalogs of old and rare instruments. Even an encyclopedia article may contend, in an age of philosophic doubt, that the violin at least has a soul. It is unlikely if in all the literature of romance and damsels there is a finer assortment of luscious adjectives than have been applied to the violin; to its moving tone, brilliant, mellow, responsive, flexible, fascinating, silver, glorious, bell-like, splendid, sweet, flute-like, far-carrying, charming, exquisite; to its appearance and varnish, golden brown, handsome, rich red, plum red, magnificent, gold red, artistic, masterful, distinguished, bold, elegant, venerable, plum-orange-red, delicate, mighty, marvelous, perfect.

Long live the king!

CORN-STALKS AND COBS IN INDUSTRY

By L. K. ARNOLD

ENGINEERING EXPERIMENT STATION, IOWA STATE COLLEGE

From hard, dense, strong material resembling polished ebony to a soft, spongy material resembling cork is the remarkable range of synthetic wood-like products produced from corn-stalks.

For the magic wand of research has waved over the great waste fields of corn-stalks, corn-cobs and straws and there have stepped forth materials that vie in beauty and utility with the finest products of our great forests. Once more the chemical engineer has taken the waste and despised things of the world and is creating from them new products for the comfort and enjoyment of mankind. Already factories are springing up out in the great middle west to bring these things into a practical reality and the farmers are looking forward to an income from otherwise waste materials. The lowly corn-stalk at last is coming into its own, where it will rank with the grain in giving value not only to the farmer but to the world.

The development of this great industry of the future is largely the outgrowth of years of patient but enthusiastic research by the department of chemical engineering and the Engineering Experiment Station of Iowa State College in an effort to be of real service to the middle west by utilizing the vast quantities of agricultural wastes. From dark, wet laboratories in the basement of the chemistry building to a new building designed especially for the department, equipped with the most modern and complete semi-commercial wall-board machinery of any laboratory in the country is one of the steps in the development of the work.

The importance of the project has secured federal support through the U. S. Bureau of Standards, which furnishes four technical research men and part of the necessary equipment. The agricultural engineering department of the college is cooperating by developing the necessary machinery for harvesting the stalks.

To the technical man the production from corn-stalks of the products ordinarily made from wood is not so extraordinary or mysterious as it might appear at first glance. To be sure, corn-stalks differ outwardly from our usual pulp woods. The slender stem of the corn-stalk varies in height from eighteen inches to twenty-four feet, although the usual height in the corn belt is from six to ten feet. It is made up of the hard outer shell surrounding a center of soft pith. This outer shell is made up of a large number of bundles of long slender fibers and tubes known as fibro-vascular bundles. These fibro-vascular bundles are also found running through the pith. Every eight or ten inches along the stem long slender leaves branch out. At these points the branching of the fibro-vascular bundles going to the leaves forms the hard dense portions of the stalks known as nodes. The soft absorbent pith is made up of flat, non-fibrous cells.

The framework of the corn-stalk, as in most plants, is cellulose, which constitutes about 45 per cent. of the total weight, as compared to the various woods containing 48 to 62 per cent. The lignin content of corn-stalks is about 31 per cent., compared to 23 to 34 per cent. in

various woods. Corn-stalks are characterized by their high pentosan content of over 27 per cent., in contrast with the common woods, which range from 7 to 25 per cent. Apparently there is very little difference between the chemical composition of the pith and outer fiber although they have widely different physical characteristics. The leaves run slightly lower in cellulose content than the stalks or husks. The cobs also run slightly lower in cellulose content and higher in pentosans. From analyses it is evident that chemically corn-stalks and cobs are not greatly different from wood although of considerably different physical properties.

The long, strong fibro-vascular bundles and the short broad pith cells of the corn-stalks are torn apart by shredding and beating in a water suspension in a paper beater or rod mill. By the time they are of the proper length they have absorbed a great deal of water and become slightly sticky on the surface, so that when pressed in a mat and dried they hold together in the form of a board. By cooking under pressure this property of sticking together is increased. The fibers are formed into the board, pressed and dried on continuous machinery.

The use of boards such as these in construction work has developed rapidly. A few years ago wall boards and insulating boards were considered only a material for use in temporary partitions or cheap repair work, while to-day thousands of square feet are going into the construction of houses of the better class. The older type wall boards are made up from paper pulp or waste paper and resemble sheets of heavy cardboard. The gypsum wall boards have a core of gypsum plaster faced on both sides with heavy paper. The insulating boards, with the exception of cork board, are made up of a mat of long fibers felted together into a relatively soft board about one half inch in thickness. The fibers are held together firmly enough to produce a board of sufficient strength but not so firmly as to eliminate the tiny air pockets and the surface air films on the fibers which give the board heat-insulating properties superior to the other boards. A great variety of raw materials have been proposed for insulating board manufacture, some of which are being commercially utilized. Boards are made from such materials as wood, wheat straw, flax straw, cork, sugar-cane waste, licorice root waste, and other wastes.

The corn-stalk insulating board is suitable as a substitute for lath and plaster, as a plaster base, or as sheathing either under wooden siding or under stone or brick veneer. It is an excellent heat insulator so that its use as a lining for refrigerators has been studied. Boards from 2 to 2½ inches in thickness have been built up by cementing or stitching together a suitable number of the 7/16- or ½-inch boards and by forming thick boards of a single layer on a special suction machine. Material equal to cork board in heat-insulation value has been produced and shown to be satisfactory substitute for the higher-priced material.

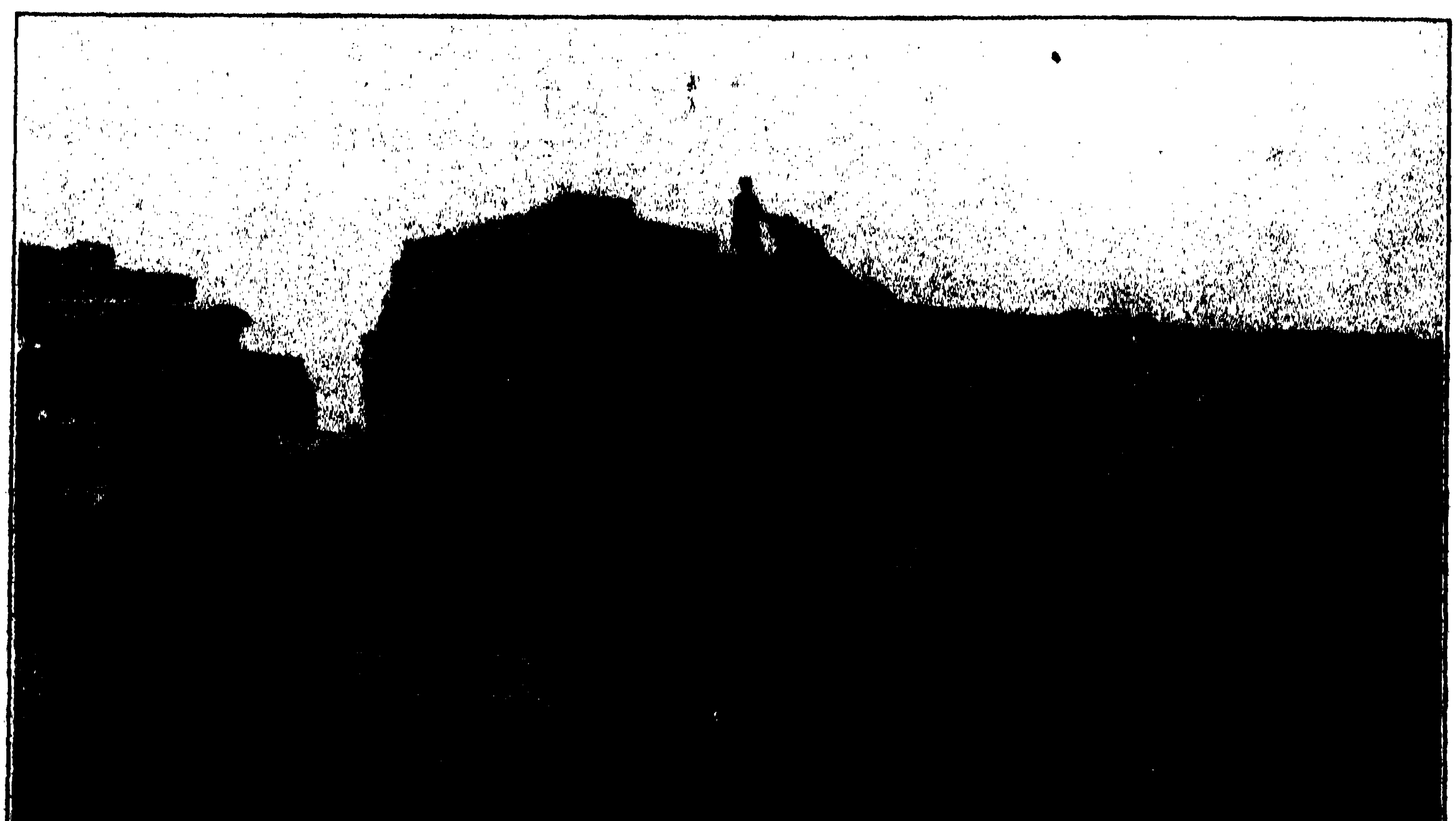
A hard dense type of board has been produced with the simultaneous application of heat and pressure in a special type of hydraulic press. This board resembles a very hard grainless wood and is suitable for many uses, such as paneling construction in Pullman cars, automobile bodies and truck bodies. Another type has been produced by pressing dry board under high pressures. This material resembles ordinary lumber.

But insulating board is only one of the things which can be made commercially from corn-stalks. Corn-stalks are now being used commercially in the production of excellent grades of paper. This

CORN-STALK HARVESTING MACHINE

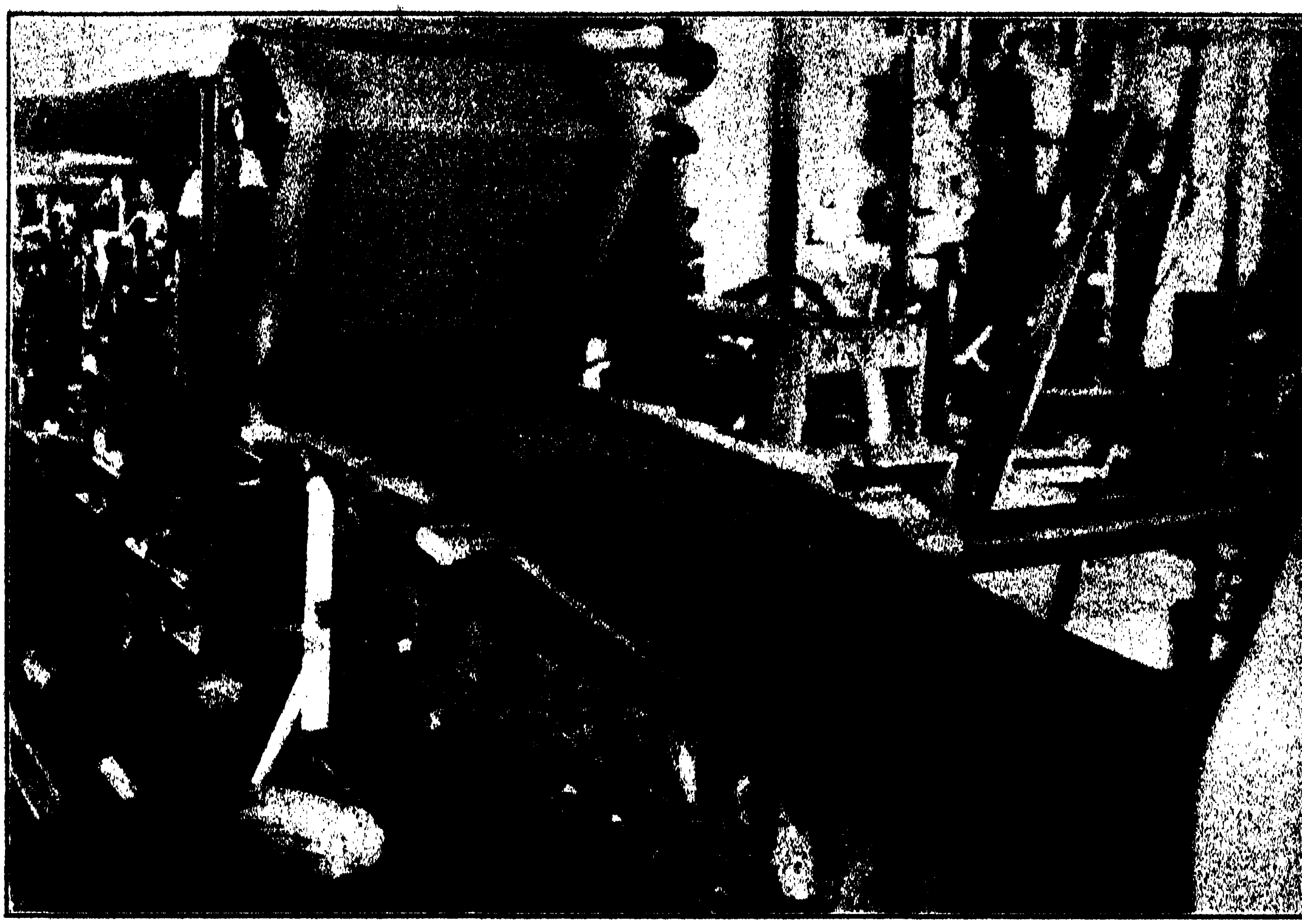
DEVELOPED BY THE AGRICULTURAL ENGINEERING DEPARTMENT, IOWA STATE COLLEGE.

is the outgrowth of centuries of effort by inventors. In most of the older methods an attempt was made to separate the outer shell and pith. In this manner good paper was produced but not at an economical cost. At Iowa State College the entire stalks have been made into paper without any attempt at separation of parts. Practically all the standard methods for producing paper pulp have been applied to corn-stalks in the laboratory. Hundreds of experiments in which small batches of shredded stalks have been cooked with varying pressure, varying length of time and varying concentrations of chemicals



PILING BALED CORN-STALKS

FOR USE OF THE CHEMICAL ENGINEERING DEPARTMENT AND THE U. S. BUREAU OF STANDARDS. (MACHINE DEVELOPED BY THE AGRICULTURAL ENGINEERING DEPARTMENT, IOWA STATE COLLEGE.)



—*Photo from the U. S. Bureau of Standards*

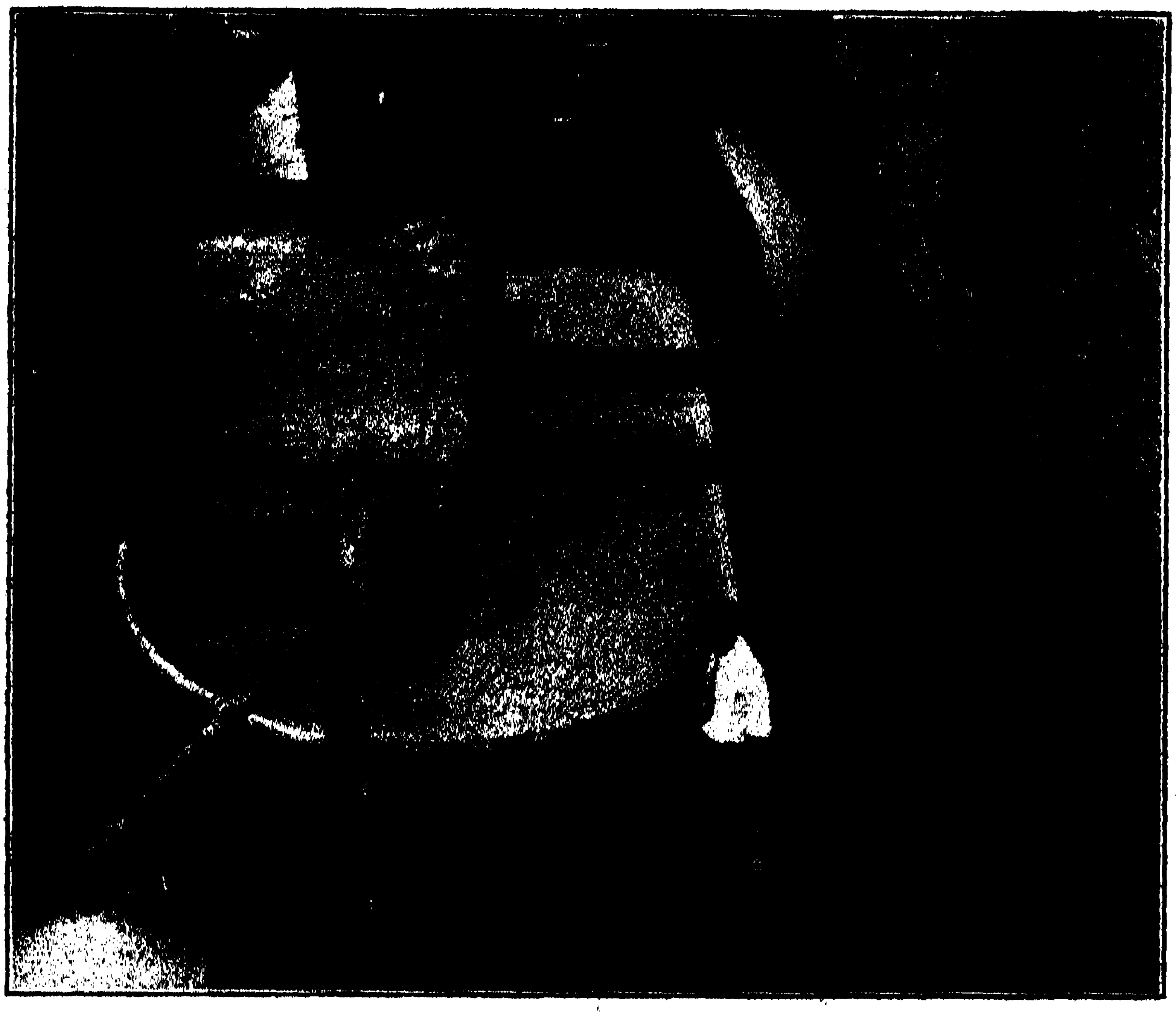
CORN-STALK WALL-BOARD LEAVING PRESS ROLLS TO DRIER

CHEMICAL ENGINEERING LABORATORY, IOWA STATE COLLEGE.

have been carried out. Each batch of pulp has been beaten, refined, screened, bleached and made into small test sheets on miniature paper equipment. As a result it was shown that good paper could be made by various chemical processes. Excellent paper of the type used in books and as writing paper can be produced by what is known as the "soda process," in which the stalks are cooked in a solution of caustic soda or lye. Paper produced by a modified soda process known as the Dörner process is now on the market. A good brown wrapping paper can be made by the Kraft process. Processes are also being developed for the production of a cheap mechanical pulp suitable for newspaper use.

By further purification of the paper pulp alpha cellulose can be produced. This is the raw material for rayon, or artificial silk, and is at the present time produced from wood and cotton. Experiments at Iowa State College showed that viscose could be produced from corn-stalk alpha cellulose, but due to lack of suitable equipment no extensive studies were made. Experimental work by a commercial organization in an eastern factory showed that high-grade rayon can be made by the three methods in common use in the United States.

The possibility of utilizing corn-stalks to replace wood as a raw material in the paper industry is of particular interest because of the rapidly decreasing supply of wood available in the United States. The great virgin forests which in the time of our forefathers stretched from the Atlantic Ocean to the Mississippi River and fringed the shores of the Pacific Ocean and the Gulf of Mexico are to-day so depleted by the inroads of the pioneer, the lumber man and the paper man that the future sup-



ONE–TON BEATER
USED IN BEATING CORN-STALK WALL-BOARD PULP.
CHEMICAL ENGINEERING LABORATORY, IOWA STATE COLLEGE

ply of wood for various uses is very uncertain. To be sure, some wood is being grown, but it is hard to convince the American business man that the growing of trees with all the hazards of storm, fire and disease, for a low return sometime in the distant future is a desirable business venture. As a result, four times as much wood is being used as is being grown. Wood for paper pulp is especially scarce, since the paper mill with its expensive layout of equipment can not, like the saw mill, follow the retreating forests back. In excess of 55 per cent. of all the 9,000,000 tons of paper used annually in the United States is imported as paper, paper pulp or pulp wood.

Corn-stalks as a raw material for paper and insulating board have the advantage of being an annual crop available year after year. The annual production of corn-stalks in the United States is estimated at 150,000,000 tons. In the corn belt they are concentrated in large quantities over relatively small areas. In Iowa, for example, one third of all the land is planted to corn each year. In parts of the state as much as 60 per cent. of the land is in corn. It is estimated that the average yield of stalks is at least 1.5 tons an acre. On this basis, using the state average of one third the land in corn, a plant operating 300 days per year could secure eighty tons of stalks per day from over a five-mile radius, or 335 tons per day over a ten-mile radius. In that portion of the state where 60 per cent. of the land is in corn a radius of five miles will yield 150 tons of stalks per day, and a radius of ten miles will yield 600 tons of stalks per day. It is evident that the length of haul for even a fairly large factory would be short.

Methods for harvesting of corn-stalks have been studied by the agricultural engineering department of Iowa State

—*Photo from the U. S. Bureau of Standards*

SHREDDER USED IN SHREDDING CORN-STALKS FOR WALL-BOARD

CHEMICAL ENGINEERING LABORATORY, IOWA STATE COLLEGE

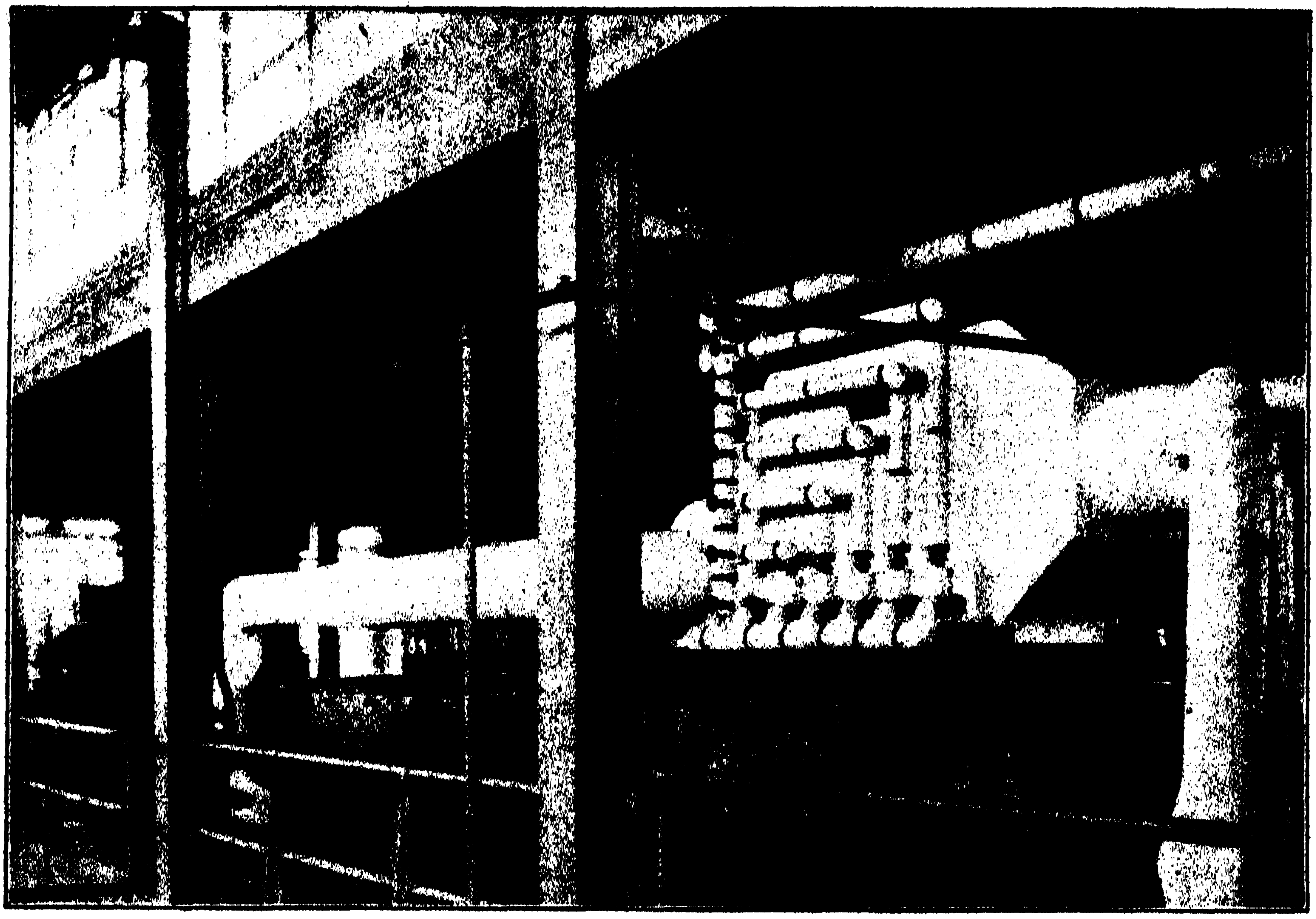
College. As a result of these studies a machine has been built which both cuts and bales the stalks as it travels through the field. This machine is a combination of a mower, a hay loader and a baler built into one machine drawn by a tractor. The stalks are cut by the mower. elevated from the ground to a hopper over the baler by the hay loader, and baled in the baler. Two men are required to operate the machine. The cost of cutting and baling, including all items, is estimated at $2.40 per ton.

The value of the corn-stalks to the farmer for use on the farm is probably small. The immature stalks, together with grain, are used in the production of silage, which is an excellent food for farm animals. The mature stalks such as would be utilized commercially have very little food value. They are sometimes plowed under, where they have a doubtful value as a fertilizer. Immense quantities of stalks are burned annually in the corn belt in order to clear the ground for spring plowing.

About 20,000,000 tons of corn-cobs are produced each year in the United States. Practically their only use in the past has been as a low-grade fuel for domestic use. Like the corn-stalks the cobs have been the subject of extensive research by the chemical engineering department and Engineering Experiment Station. They have been destructively distilled, producing products similar to wood, as charcoal, acetic acid, formic acid, methanol, tar, illuminating gas and acetone. The charcoal has been shown to be an excellent feeding charcoal. After suitable treatment it forms an excellent decolorizing charcoal. As in the wood distillation industry the cobs are heated to a high temperature in a closed retort and the vapors condensed in suitable condensers.

It has been known for a long time that the pentosans, which are characteristic constituents of corn-cobs, could be utilized as a source of furfuraldehyde or, as it is commonly known, furfural. Extensive studies were carried on in the production of furfural from corn-cobs. The method worked out was to distill a mixture of dilute hydrochloric acid and ground corn-cobs. The vapor was condensed to a mixture of furfural and water which was fractionated to give almost pure furfural. Furfural, like formaldehyde, reacts to form a hard resin similar to bakelite. This rèsin may be used in production of certain varnishes, and, mixed with a suitable filler such as wood or corn-cob flour, as a molding resin. Instead of producing furfural from the cobs and then treating furfural with phenol, the plastic resin may be formed in the ground cobs by the addition of hydrochloric acid and phenol. The cellulose material of the cob remains in the resin, acting as a filler. The result is a low-grade plastic produced at a considerably lower cost than is possible by the other method. Furfural has excellent preservative properties, having been used in veterinary embalming fluid, in the antiseptic treating of seeds, and for other similar purposes. Furfural and some of its derivatives are excellent solvents for nitrocellulose and cellulose acetate. It is an excellent varnish remover. It was used in "dope" for airplane wings during the war. A number of dyes and anesthetics were prepared from furfural in the chemistry department of Iowa State College. Various furfural derivatives are excellent accelerators for use in the curing of rubber. Furfural can be used to replace gasoline, although

CHEMICAL ENGINEERING BUILDING, IOWA STATE COLLEGE



—*Photo from the U. S. Bureau of Standards*

COE ROLLER-TYPE DRIER USED FOR DRYING WALL-BOARDS
CHEMICAL ENGINEERING LABORATORY, IOWA STATE COLLEGE

at the present time it is too expensive for this purpose. Furfural, as a result of the extensive research on its production from various raw materials, is now made in large quantities at Cedar Rapids, Iowa, from oat hulls. While the yield from corn-cobs is greater, the oat hulls are used since they are segregated in great quantities as a waste product of the oatmeal industry. As a result of the large scale production the price of furfural has dropped in the last few years from $30 to 15 cents per pound.

When corn-cobs are digested under pressure in water a strong adhesive can be produced. If dilute mineral acid is added a solution of xylose can be produced. Xylose is a sugar which up to the present time has been produced in large quantities only as a syrup. Since xylose has practically no food value it probably can be used by diabetic patients without the harmful effects produced by cane or beet sugar.

Oxalic acid has been produced in the laboratory by fusing corn-cobs with caustic soda and also by oxidizing corn-cobs with nitric acid. Considerable experimental work was done on the softening of water by using the impure corn-cob-alkali fusion mass direct without separating out the oxalic acid.

Various other uses have been found for corn-cobs. They have been ground to a flour which may be substituted for wood flour in many uses. It has been made into very good punk and incense. Ground cobs have been used in curing concrete floors in place of sawdust and have been substituted for bran for removing the oil from tin plate in the tin-plating industry. Corn-cobs have been used successfully in bee-smoking and in smoking of meats.

THE PROGRESS OF SCIENCE

FIFTY YEARS OF THE UNITED STATES GEOLOGICAL SURVEY

On March 21, 1929, the U. S. Geological Survey celebrated the fiftieth anniversary of the appointment of its first director. President Hoover, who at one time was a member of the organization, received the present members at the White House, and Mrs. Hoover, who was trained as a geologist, gave them a brief talk. In the afternoon, at a meeting held in the National Museum, Dr. Ray Lyman Wilbur, secretary of the interior; Dr. H. Foster Bain, secretary of the American Institute of Mining and Metallurgical Engineers; Dr. Arthur E. Morgan, president of Antioch College; Dr. Henry Fairfield Osborn, president of the American Museum of Natural History; Dr. Arthur L. Day, director of the Carnegie Geophysical Laboratory, and Dr. John C. Merriam, president of the Carnegie Institution of Washington, made appropriate addresses. In the evening nearly six hundred members and friends of the Geological Survey gathered at a banquet at the Washington Hotel.

At the afternoon meeting the development of the survey and its purposes, ideals and accomplishments were outlined by Dr. Bain, a summary of whose address THE SCIENTIFIC MONTHLY has been given the privilege of printing.

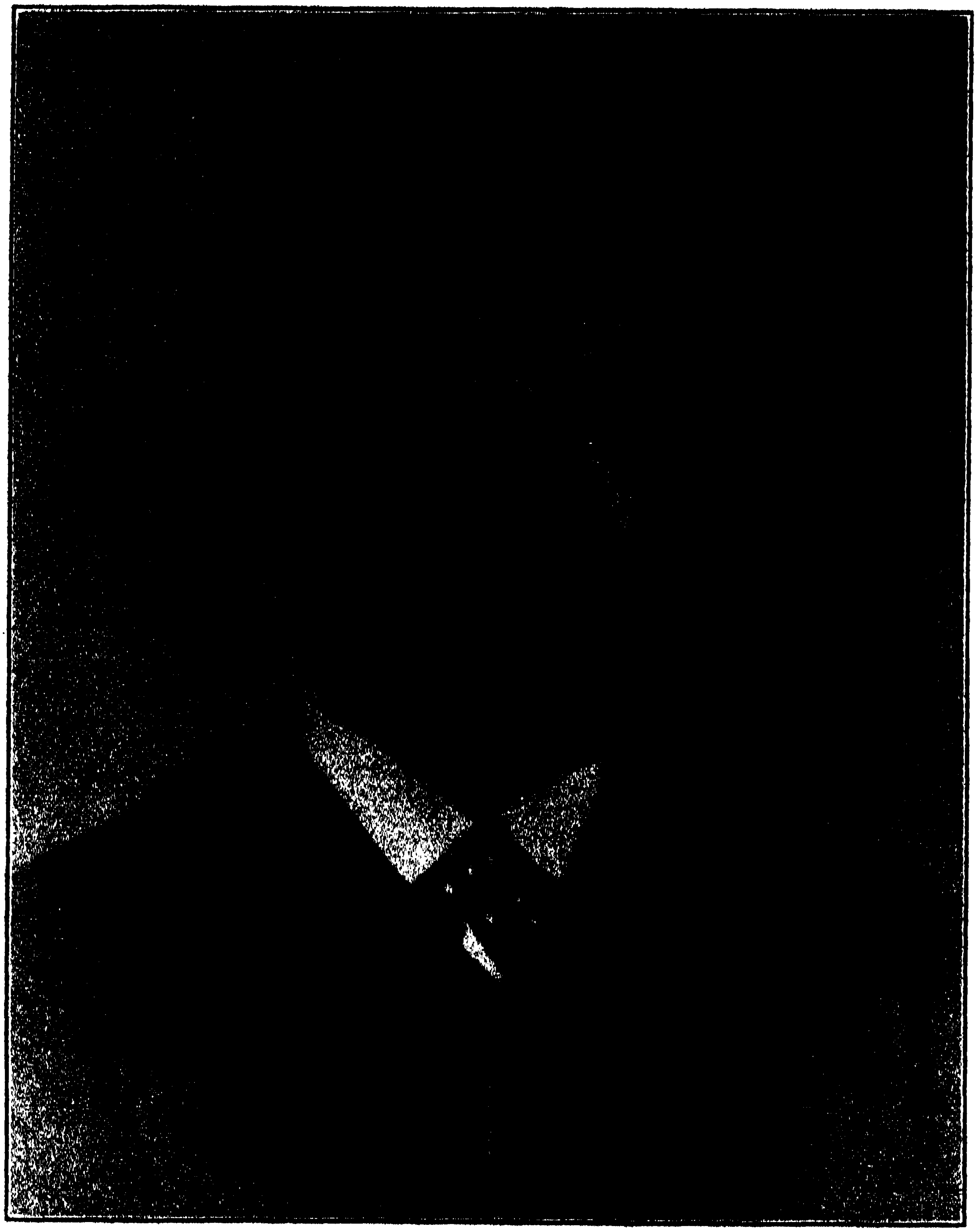
The U. S. Geological Survey was formed fifty years ago by the consolidation of four distinct organizations. These surveys, though each had an official title, have long been best known by the names of the men who directed them. Clarence King, John W. Powell, Geo. M. Wheeler and Ferdinand V. Hayden were true path breakers, and they left the impress of their personalities on their times and their country. King, who was made the first director of the new organization, was a mining engineer belonging to that group of brilliant engineers of foreign training who first in any large way brought science to the service of American mines. The Fortieth Parallel Survey, which he directed, worked in a definite field, from California to Colorado, and had a systematic plan of geologic and topographic mapping covering the whole area, followed by studies in structure and even in the technology of mining.

Major Powell, who later became the second director, was a many-sided man. A study of his work and reports gives the impression of a powerful mind avid for contacts in many directions. It was Powell and the men of his group, probably, who kept the Geological Survey from becoming merely a different type of mining bureau. Powell was interested in the lands, the forests and the waters, and in man's relations to all these, as well as to mines. It was the Powell influence which led the survey to foster studies of the Indians and resulted in the creation of the Bureau of American Ethnology. The same influence was responsible for the large part played by the survey in initiating the Forest Service and the Reclamation Service. Powell the explorer gave us the Grand Canyon, but he also gave us ideas; it would be appropriate to refer to him, for example, as the "Father of Physiography."

Wheeler was an engineer officer, and to him, apparently, we owe the plan for a complete topographic map with the system of quadrangle units. The geologic studies conducted by him were not systematic, like those of the King survey, but they were highly significant. One need only mention Gilbert and Russell, two members of the Geological Survey who came from the Wheeler organization, to indicate how great was its contribution to the fundamental problems of western geology.

The Hayden survey was in many ways the most characteristically scientific group of the four. The impress of the Philadelphia Academy of Natural Sciences was strong upon it, and it gave a powerful impulse to the study of paleontology and other scientific branches. Hayden gave us the Yellowstone and through that our great national park system, but he did even more. He gave us Holmes, Peale and Gannett—to name only three of the great leaders developed under his guidance.

Such an assemblage of men and plans gave the new survey the ideals that have governed it for half a century. Beginning as a study of the public domain, it promptly became truly

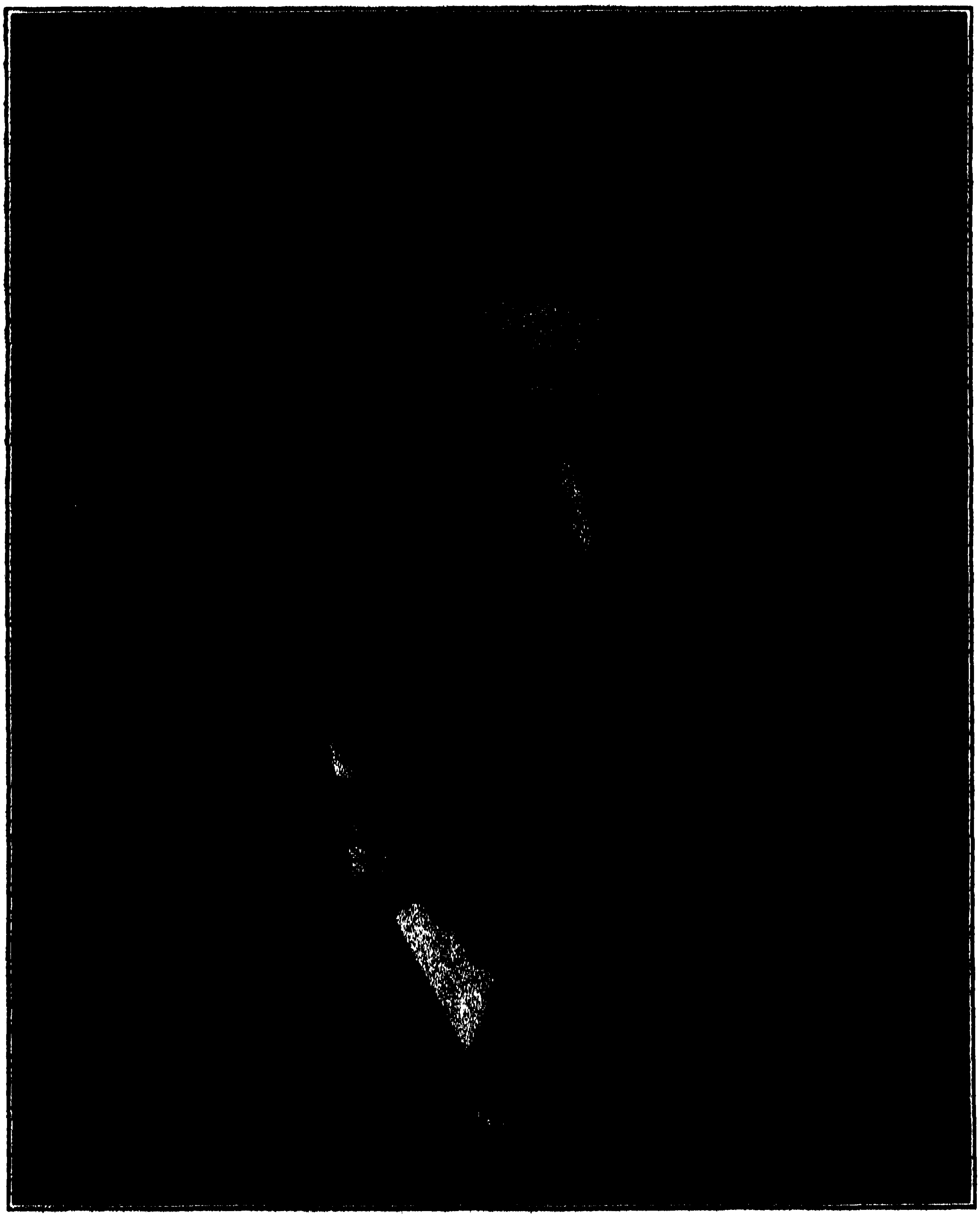


CLARENCE KING

FIRST DIRECTOR OF THE UNITED STATES GEOLOGICAL SURVEY.

national in scope. It was from the beginning scientific and systematic, but always with a most sympathetic attitude toward the problems of the engineer and the industrialist. Wisely it has elected to be the designer rather than the builder of the bridge over which industry functions. It has encouraged private enterprise, and with rare good sense has mothered new bureaus to carry out plans developed within its own organization rather than attempted unwieldy expansion.

No part of the field of geology has been neglected, and always leaders have been developed. King brought over Zirkel to apply the new art of microscopic petrography; Cross, Iddings and F. E. Wright kept up the succession. In the study of ore deposits King, Emmons, Hague and Becker formed the first great group, with occasional help from Pumpelly and such young men as Hammond and Hoover, who later became world famous. The second generation of students of ore genesis were equally able men. Lindgren, Spurr and Ransome, with the young men they trained, have set new standards in all parts of the world. In the Lake Superior region Irving, Van Hise and Leith have kept up the succession, and in petroleum geology the survey has almost created a new field, despite the credit properly to be given to others, especially I. C. White. Willard Hayes and the men associated

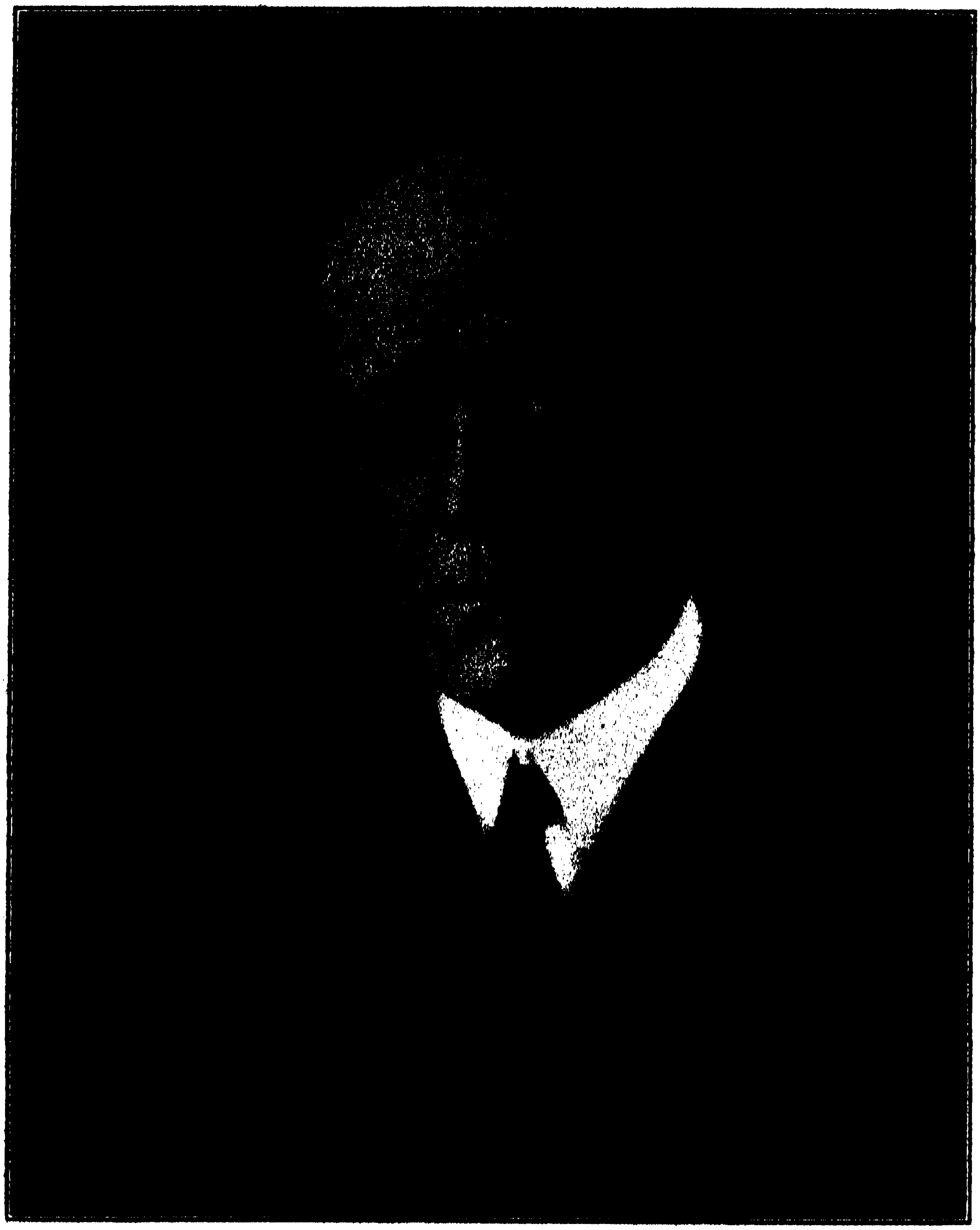


JOHN W. POWELL

SECOND DIRECTOR OF THE UNITED STATES GEOLOGICAL SURVEY.

with him were truly founders. The great impulse toward systematic study of American coal fields came from the Second Geological Survey of Pennsylvania, but the U. S. Geological Survey advanced the work far beyond its old scope and refined and improved the methods. In this work M. R. Campbell introduced exactness, ultimately leading to structural contour maps; E. W. Parker established the tradition of economic study, and J. A. Holmes fathered the introduction of technology. G. O. Smith and F. G. Tryon keep the old tradition well alive, and that fruitful partnership, I am glad to note, survives the operation of transfer of one of the two men to another bureau.

Preferring always to do well the work in its own field rather than to dissipate energy and resources, the survey has been mother to four separate bureaus and has played a large part in molding other organizations. The Bureau of American Ethnology, which was the first to be set off, has done work of lasting value in the study of our first Americans, and Powell, McGee and Holmes, three of its great leaders, were survey men. The Forest Service was formed around a survey division as a nucleus, and it is not too much to say that the early national forests were largely selected by survey men, just as Director Walcott guided the legislation creating them. For years, even after the Forest

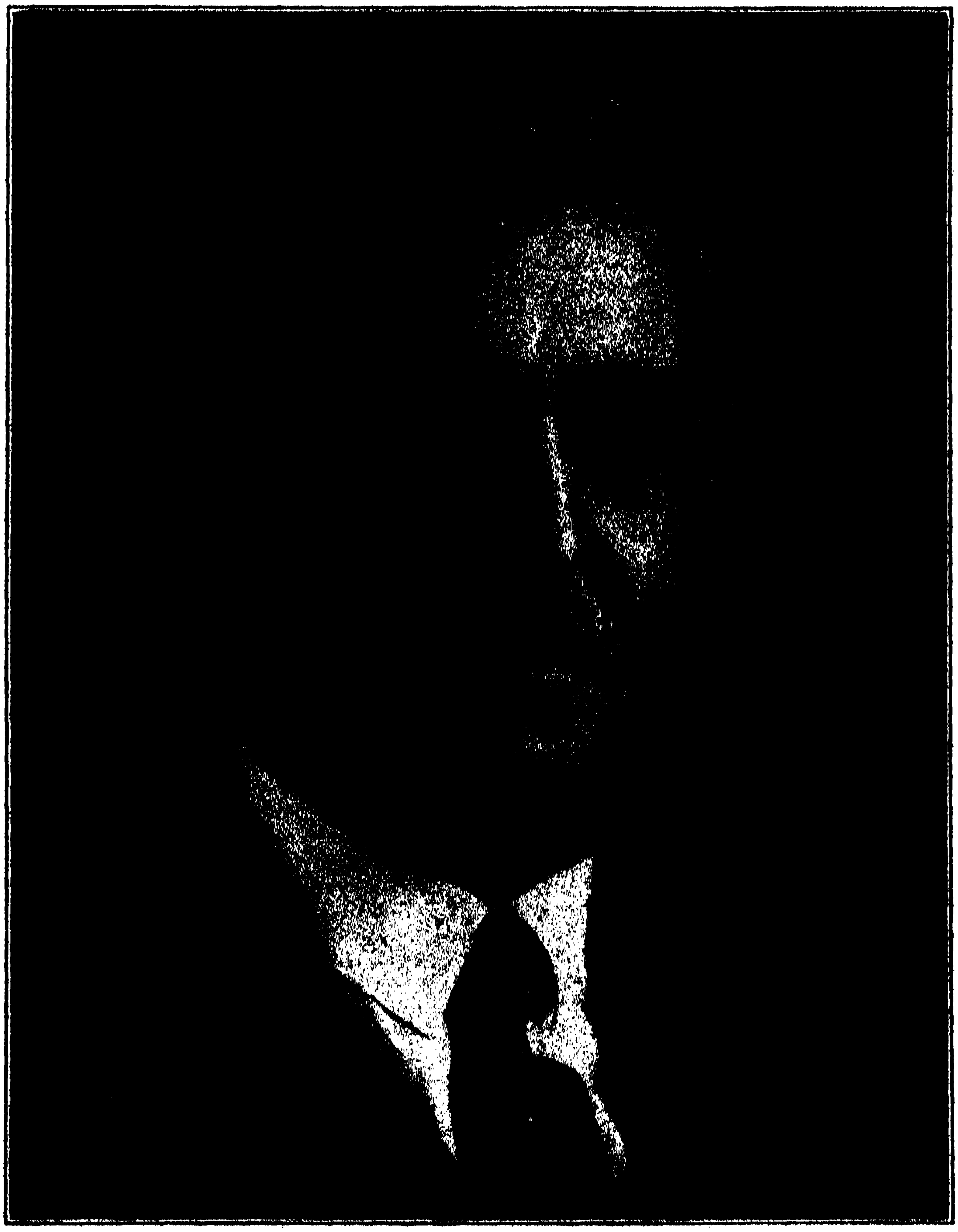


CHARLES D. WALCOTT

THIRD DIRECTOR OF THE UNITED STATES GEOLOGICAL SURVEY.

Service set up independent housekeeping, Henry Gannett was a power in its councils. The Reclamation Service grew directly out of the stream gaging and Powell's interest in arid lands. The first two directors, Newell and Davis, were survey men, and the topographic branch especially contributed heavily to its personnel. The Bureau of Mines grew out of a committee of survey members, later the technologic branch, and finally, in 1910, was set off to form a new bureau. All its directors except one have been former survey men. The broadening of the census into something more than a mere counting of noses began with the tenth census, in which survey men took a prominent part. The Federal Power Commission even now depends on the survey for much of its staff work. The Geophysical Laboratory of the Carnegie Institution was a direct outgrowth of the old physics section of the survey, and Director Walcott had a large share in organizing it.

So, wherever we turn, in science, engineering or industry, we see the fructifying influence of the survey. Perhaps its greatest contribution is one not often realized—the large part it has played in teaching the public the fundamental importance of minerals to our civilization and the need of molding legislation and practice toward their wise use and conservation. Throughout its fifty years of service it has con-

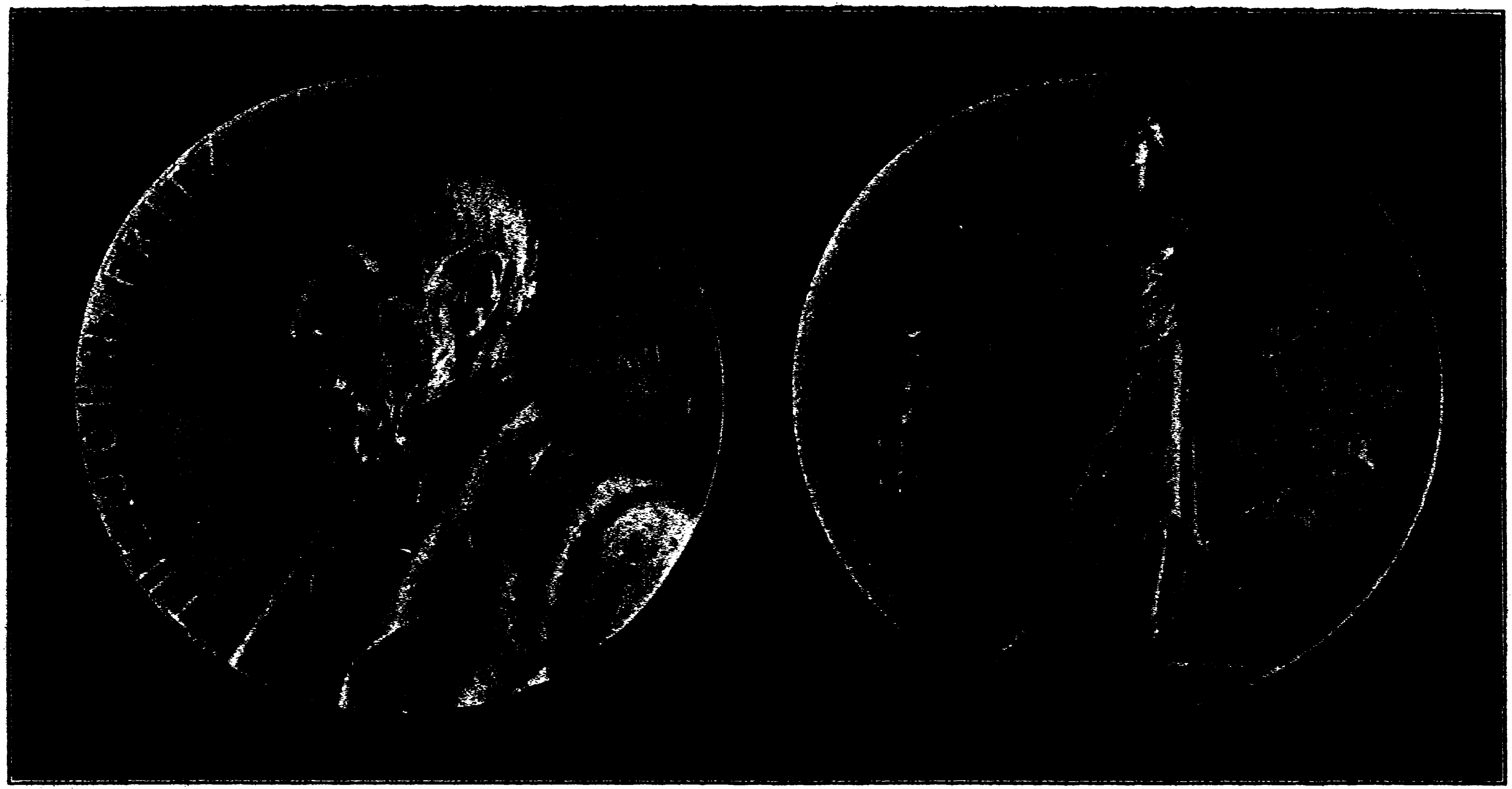


DR. O. S. SMITH

PRESENT DIRECTOR OF THE UNITED STATES GEOLOGICAL SURVEY.

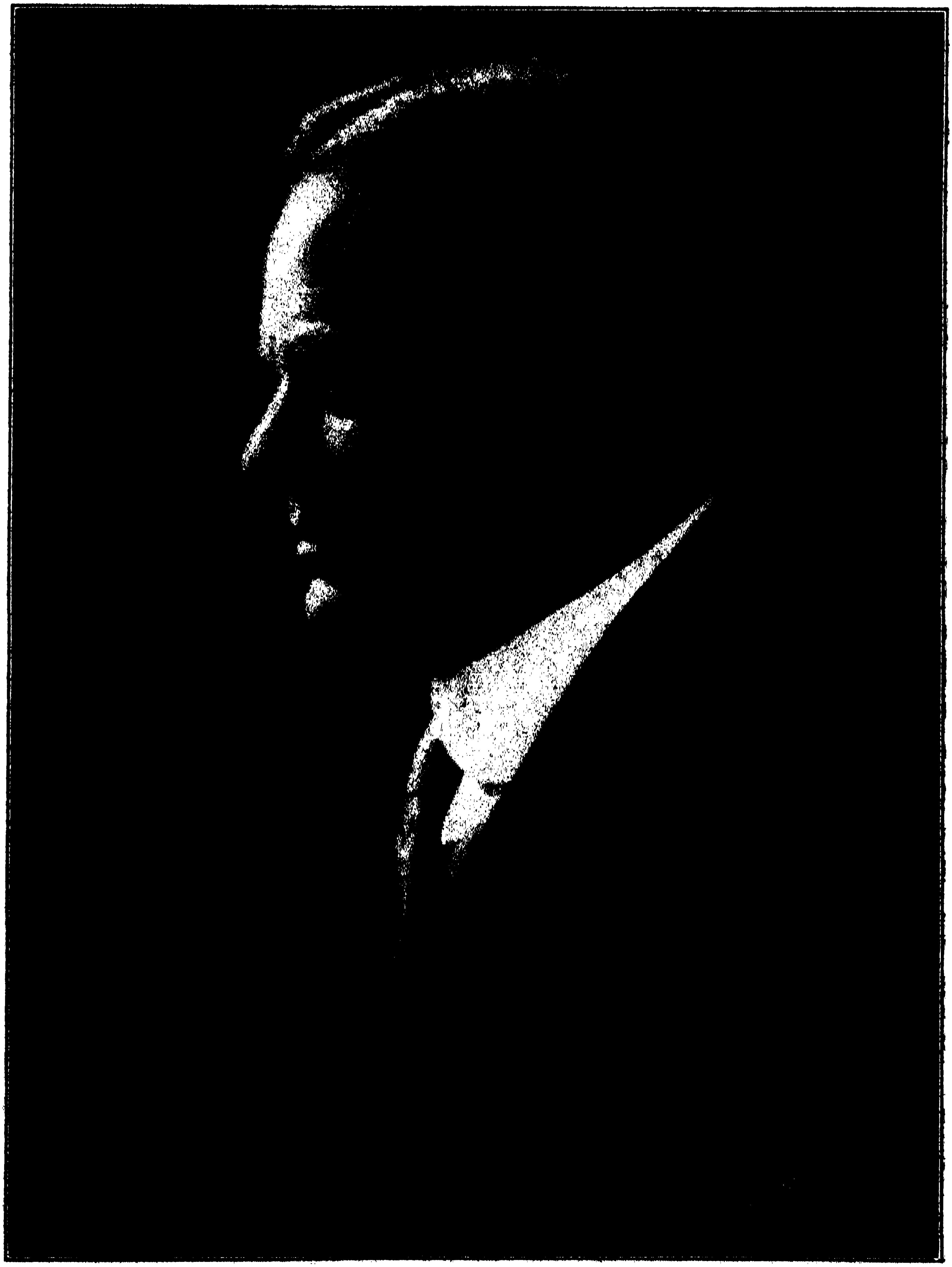
stituted a day-by-day example of the possibility of applying service in industry to the benefit of the nation and the people.

The appropriations for the work of the survey have increased from $100,000 for the fiscal year 1880 to over $2,000,000 for the fiscal year 1930. The total expenditures during the life of the survey have been about $75,000,000, including nearly $10,000,000 of state cooperative funds. The published reports by which the Geological Survey's work are made available aggregate over 400,000 pages and occupy 120 feet of shelf space. Other organizations which are in a real sense children of the Geological Survey, their work having been started by the survey, include the Bureau of Reclamation, the Bureau of Mines, the Bureau of American Ethnology, the Forest Service and the Geophysical Laboratory of the Carnegie Institution.



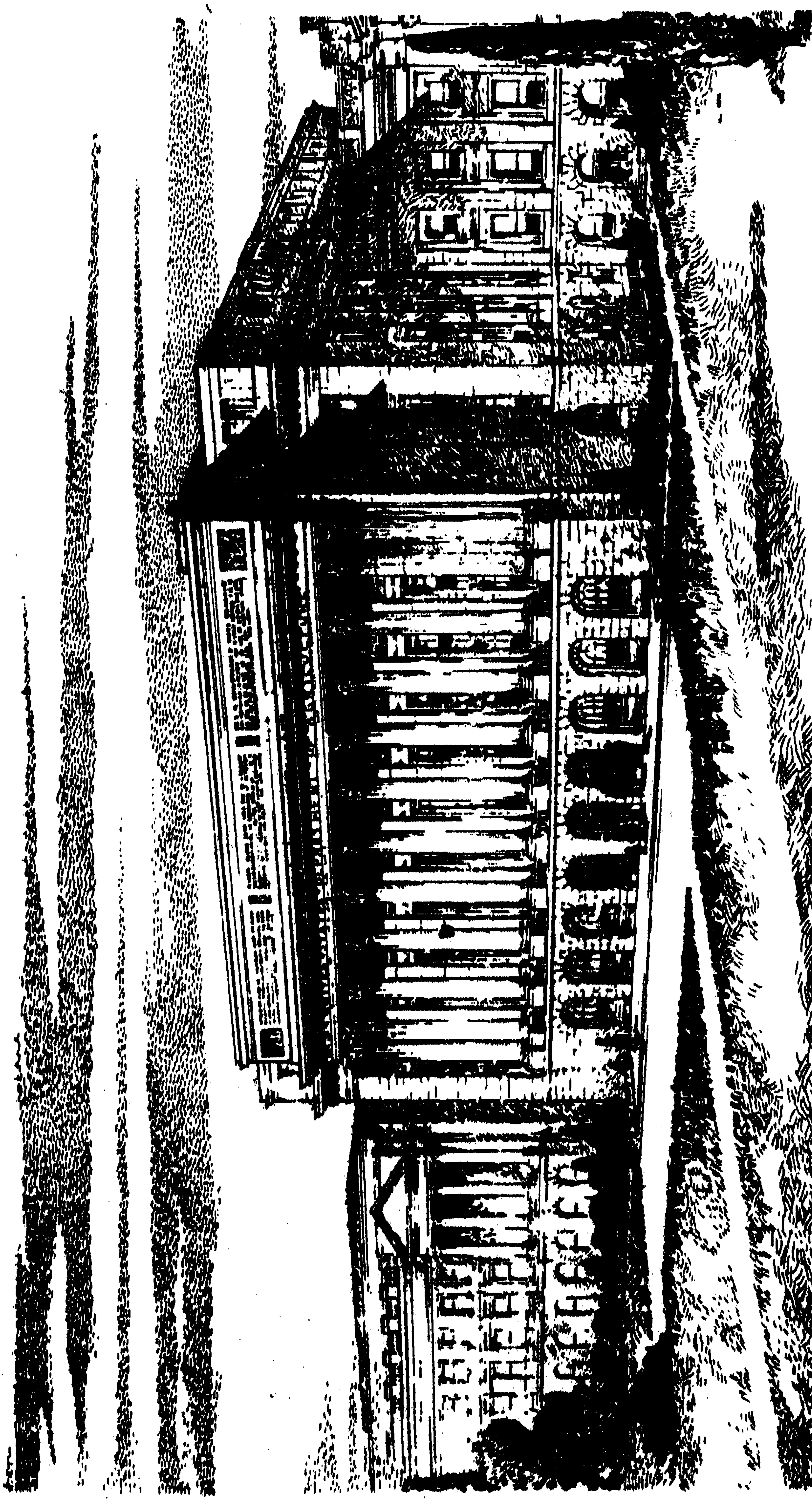
THE JOHN FRITZ GOLD MEDAL

To be presented to President Herbert Hoover during the last week in April. The medal is awarded annually for notable scientific or industrial achievement by the four national engineering societies: the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, the American Society of Mechanical Engineers and the American Institute of Electrical Engineers. The medal was awarded to Mr. Hoover in October, 1928, the decision having been made more than a year before his election to the presidency.



PRESIDENT HERBERT HOOVER

A PHOTOGRAPH TAKEN IN THE FALL OF 1928.



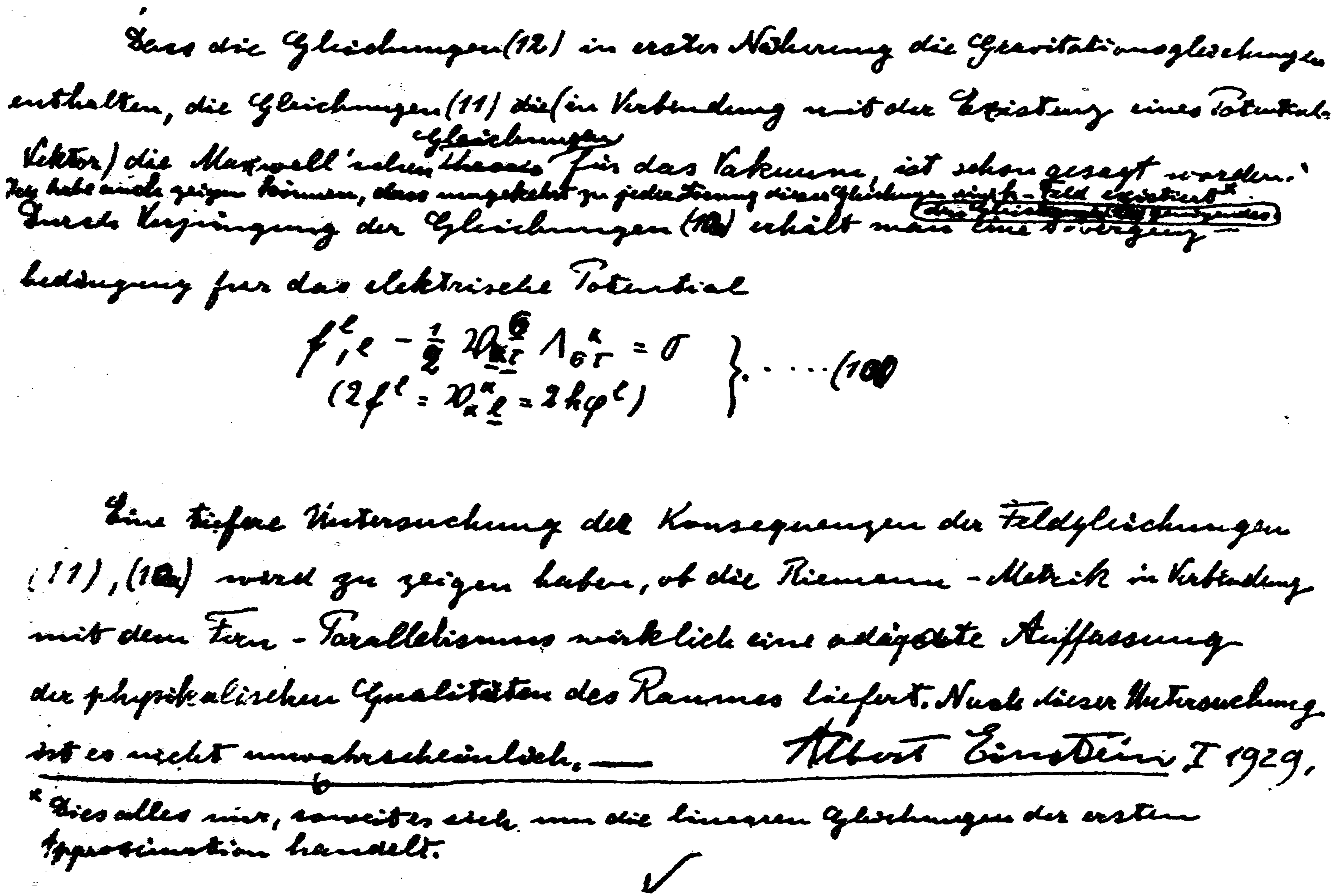
ARCHITECT'S DRAWING OF THE NEW BUILDING OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

THE NEW AGRICULTURAL BUILDING AT WASHINGTON

THIS is the architect's drawing of the new administration building of the Department of Agriculture in Washington, connecting the east and west wings, which are now standing and occupied. The building will be located on the Mall, just east of the Washington Monument. It will have an impressive entrance lobby and staircase. In the interior finish of the lobby several different kinds of marble will be used. The base of the building will be of granite and the superstructure and Corinthian columns of marble. The main five-story part will inclose a court, which will be paved, on a level three steps below the general level of the ground floor, and will be glassed over on a level with the second floor. The court will be devoted to decorative purposes, not being intended for offices of any kind. This picture is of the main façade, facing on the Mall, looking north on Thirteenth Street beyond the Mall. The offices of the secretary of agriculture will occupy the second floor front, just behind the columns. The rest of the unit will be occupied by the offices of the assistant secretary, the various directors and other administrative officers. A feature of special interest on the façade is the entablature, the long panel resting upon the capitals of the columns. On this entablature will be engraved inscriptions appropriate to the nature of the purpose for which the building will exist. The total amount authorized for the construction of the central part shown above is $2,000,000. The design shown was produced by Rankin and Kellogg, architects, of Philadelphia, and approved by James A. Wetmore, acting supervising architect of the Treasury Department.

At this time the steel frame and floors are completed and the setting of the exterior marble has reached nearly to the second floor. The completed structure, including the east and west wings and the connecting building shown at the left, will have a frontage of 750 feet. In the accompanying picture part of the east wing is shown, the west wing, lying to the right of the new building, not appearing in the architect's drawing.

In addition to the administration building, which will connect the two existing wings constructed some years ago, the government building program includes the erection for Department of Agriculture activities of a very large building, of an extensible type, on three squares of ground which are now being acquired by the government just to the south of the location of the administration building. At present the offices and laboratories of the Department of Agriculture in Washington are scattered in more than forty buildings in different parts of the city. The erection of the new buildings will bring these scattered activities together and this will not only greatly simplify the work but will prove a tremendous convenience to the many visitors to the department, who now find it very difficult to locate just the office with which they desire to transact business. The department has grown tremendously during recent years. Its employees in Washington now number about six thousand, with sixteen thousand more outside of Washington. Its activities include not only the service to farmers all over the country but also the Weather Bureau, the Forest Service, the Bureau of Public Roads, the Bureau of Home Economics, and the enforcement of laws, such as the pure food law, the meat inspection law and many others which directly affect the health and welfare of the general public.



Dass die Gleichungen (12) in erster Näherung die Gravitationsgleichungen enthalten, die Gleichungen (11) die (in Verbindung mit der Existenz eines Potential-Vektors) die Maxwell'schen Gleichungen für das Vakuum, ist schon gesagt worden.*
Ich habe auch zeigen können, dass umgekehrt zu jeder Lösung dieser Gleichungen ein ... Feld existiert.
Durch Verjüngung der Gleichungen (10a) erhält man eine Divergenz-bedingung für das elektrische Potential

$$\left.\begin{array}{l} f^{\iota}{}_{,\iota} - \frac{1}{2}\mathfrak{V}^{\sigma}_{\underline{\kappa\tau}}\Lambda^{\kappa}_{\sigma\tau} = 0 \\ (2f^{\iota} = \mathfrak{V}^{\kappa}_{\kappa\underline{\iota}} = 2k\varphi^{\iota}) \end{array}\right\} \ldots\ldots (10b)$$

Eine tiefere Untersuchung der Konsequenzen der Feldgleichungen (11), (10a) wird zu zeigen haben, ob die Riemann-Metrik in Verbindung mit dem Fern-Parallelismus wirklich eine adäquate Auffassung der physikalischen Qualitäten des Raumes liefert. Nach dieser Untersuchung ist es nicht unwahrscheinlich. —

Albert Einstein I 1929.

* Dies alles nur, soweit es sich um die linearen Gleichungen der ersten Approximation handelt.

FACSIMILE REPRODUCTION OF A PORTION OF PROFESSOR EINSTEIN'S MANUSCRIPT

THE LOWER HALF OF PAGE 7 OF PROFESSOR ALBERT EINSTEIN'S ORIGINAL MANUSCRIPT BEARING THE TITLE "ZUR EINHEITLICHEN FELDTHEORIE." THE COMPLETE MANUSCRIPT IN DR. EINSTEIN'S HANDWRITING HAS BEEN PRESENTED TO THE OLIN LIBRARY OF WESLEYAN UNIVERSITY.

THE SCIENTIFIC MONTHLY

JUNE, 1929

REVEALING THE TECHNICAL ASCENT OF MAN IN THE ROSENWALD INDUSTRIAL MUSEUM

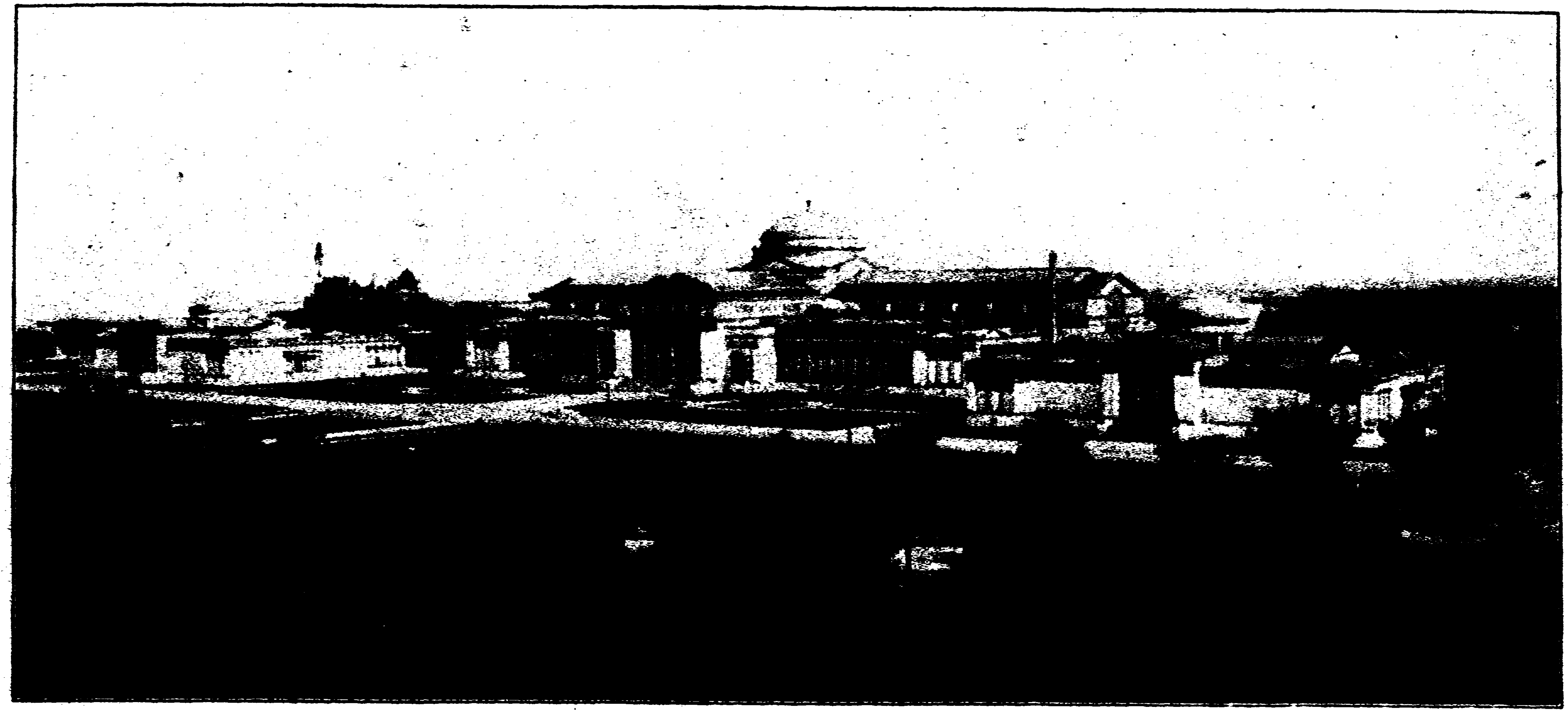
By WALDEMAR KAEMPFFERT

DIRECTOR OF THE ROSENWALD INDUSTRIAL MUSEUM OF CHICAGO

In 1903 Dr. Oskar von Miller invited representatives of German industry to discuss with him the creation in Munich of a museum in which the masterpieces of science and engineering were to be preserved and in which their relation to industry was to be set forth. He had more in mind than a storehouse to which the public would be admitted. Machines were to move. Moreover, the public was to make them move, so far as possible, by pushing the buttons or pulling the levers that controlled the driving energy. There were to be paintings and charts to supply as simply and interestingly as possible facts that could not be discovered by a study of engines which had been cut open to reveal mechanism ordinarily concealed. Dioramas, miniature stages on which apparatus is mounted amid a dramatic setting, were to disclose the circumstances that make the principal industrial processes. Daylight motion-picture projectors were to supplement the exhibits.

Von Miller's proposal was received with acclamation. In a year the now famous Deutsches Museum was actually in existence, housed in the abandoned National Museum. The rulers of the German states from the emperor down, every important manufacturing corporation, every city in Bavaria, contributed either machines or money to make the Deutsches Museum the most conspicuous success of its kind in Europe. In a new building, which was formally opened in 1925 and which bears witness to the devotion and energy of Dr. von Miller, some sixty thousand objects of scientific and technical interest are displayed. Over one million persons pass through the museum in the course of a year, and this in a city which has a population of 680,000. To inspect all of the marvels that have been painstakingly gathered and systematically arranged entails a promenade of about ten miles, and yet most of the million face it with eagerness.

It was not a revolutionary proposal in which Dr. von Miller succeeded in interesting German industry. In the early annual reports of the Deutsches Museum he generously acknowledges his indebtedness for his inspiration to the Conservatoire des Arts et Métiers, founded at the close of the eighteenth century in Paris, and to the Science Museum of South Kensington, which was the outgrowth of the Crystal Palace Exposition of 1851. But the Conservatoire was but an adjunct to the École Centrale, and therefore but a repository for historic models, and the Science Museum, although some of its machines actually moved, had, in 1903, neither well-planned nor well-balanced collections. Certainly no museum director who preceded him had von Miller's magnificent



—*Courtesy of the Field Museum of Natural History*

THE OLD FINE ARTS BUILDING

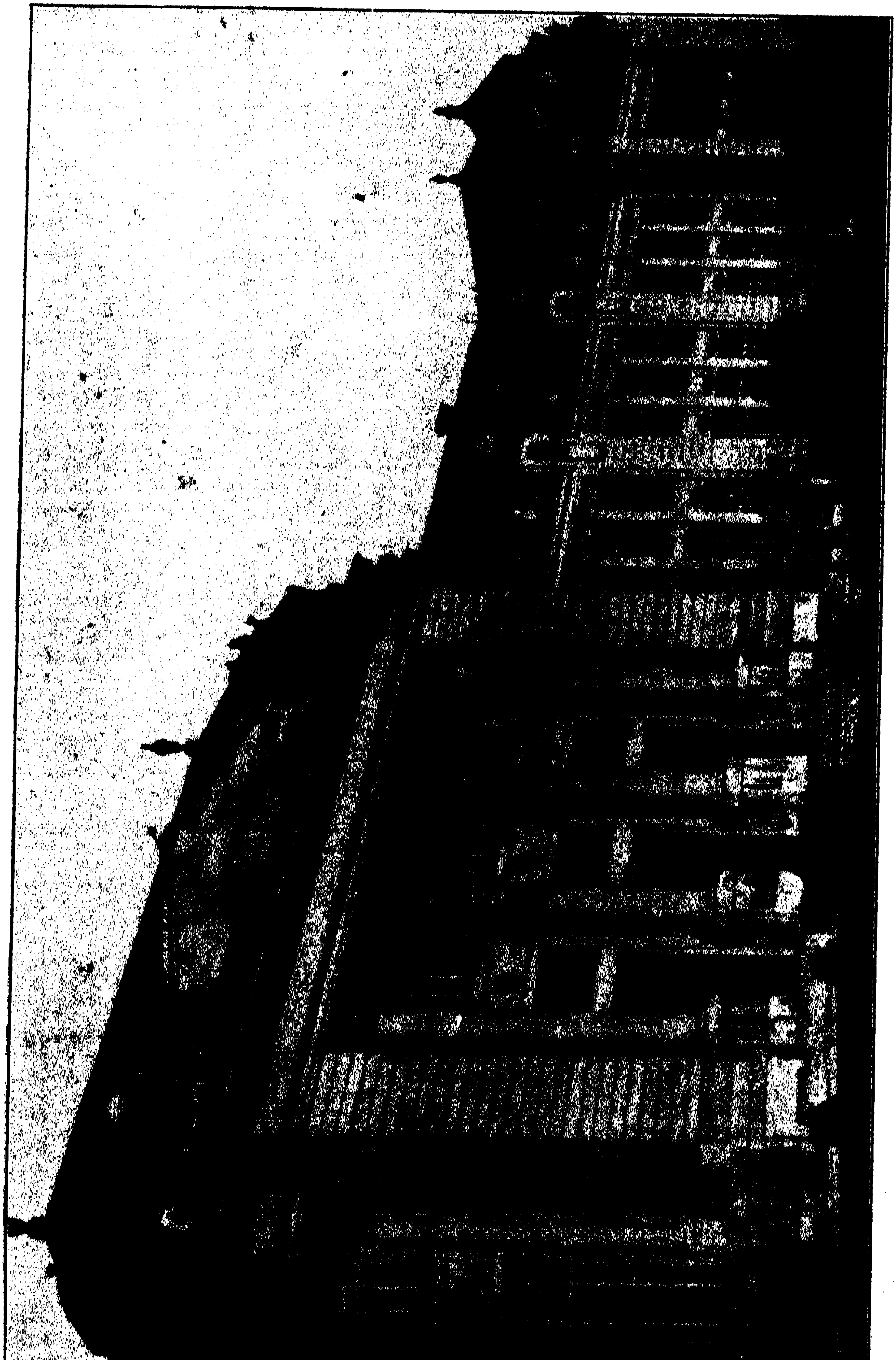
THE ROSENWALD INDUSTRIAL MUSEUM WILL BE EXACT REPLICA OF THE OLD FINE ARTS BUILDING (HERE SHOWN) LEFT OVER FROM THE WORLD'S COLUMBIAN EXPOSITION OF 1893. THIS REPLICA OF STONE WILL COST $5,000,000 TO BE DEFRAYED BY THE SOUTH PARK COMMISSIONERS AND WILL BE ERECTED IN JACKSON PARK, CHICAGO, ON THE OLD SITE. MR. JULIUS ROSENWALD HAS ENDOWED THE MUSEUM WITH $3,000,000 WHICH SUM IS TO BE SPENT FOR EXHIBITS AND OTHER EQUIPMENT. A COLLECTION WHICH WILL ULTIMATELY BE WORTH AT LEAST $30,000,000 WILL BE HOUSED IN THE STRUCTURE.

conception of a museum which would range over the whole field of science and technology, lay bare the mysteries of industrial processes and present the most recondite technical subjects so fascinatingly that the reciprocations of a locomotive piston in its cylinder or the mining of coal would be almost as arresting as a play.

Struck by the brilliant success of Dr. von Miller and by the anomaly that, despite its achievements in science, engineering and industry, the United States had nothing that corresponded with the Deutsches Museum, Mr. Julius Rosenwald decided to establish in Chicago not merely an imitation but an institution which would utilize the experience of Europe as a foundation and which would develop the technique of Munich. He laid his plan before the Commercial Club of Chicago, which is composed of representative business men, and in 1926 expressed his willingness to endow an American technical museum with the sum of $3,000,000 to be spent for equipment alone. The club formed a board of trustees[1] and undertook the task of creating the museum and administering the fund. The city likewise responded and generously. In Jackson Park stood the old Fine Arts building, a disintegrating reminder of the World's Columbian Exposition of 1893 and an architectural masterpiece which, in the opinion of the late Augustus Saint Gaudens, "is the finest thing done since the Parthenon." The South Park commissioners were authorized to issue bonds to the value of $5,000,000 for the purpose of reproducing the structure in permanent form so that it could safely exhibit scientific and technical collections, which, if the Deutsches Museum is a criterion, will ultimately be so large that they will be worth at least $30,000,000. Thus was born the institution provisionally called the Rosenwald Industrial Museum. By the summer of 1929 the work of erecting a replica will begin. By 1933 it is hoped that the museum will not only be completed but actually open to the public, although there is no intention of filling by that time halls as vast as those of the Deutsches Museum.

The magnificent scientific and industrial museums of Europe, pioneers in a new form of visual education, content themselves with explaining technical principles and processes with admirable simplicity. Is this enough? At the outset the sponsors of the Rosenwald Industrial Museum reached the conclusion that the time had come when a forward step must be taken and that Chicago, because of its geographical situation and its industrial importance, seemed called upon to become an American pioneer in this field of visual education. On the experience acquired by Munich, Paris and London an institution is to be reared that has no exact counterpart anywhere, despite the outward similarity that it will bear to the technical museums of Europe. And this forward step is to be taken by amplifying foreign practice—by presenting not only machines in motion but also by illuminating the social phases and cultural aspects of science and technology.

[1] W. R. Abbott, president of the Illinois Bell Telephone Co.; Sewell L. Avery, president of the U. S. Gypsum Co.; the late Edward F. Carry, president of the Pullman Co.; Thomas E. Donnelly, president of the R. R. Donnelly Co.; John V. Farwell, director of the National Bank of the Republic; Robert P. Lamont, Secretary of Commerce of the United States; Charles H. Markham, chairman of Illinois Central R. R. Co.; Charles Piez, chairman of the Link Belt Co.; Theodore W. Robinson, vice-president of Illinois Steel Co.; Julius Rosenwald, chairman of Sears, Roebuck and Co.; Joseph T. Ryerson, president of Jos. T. Ryerson and Son; Albert A. Sprague, director of Sprague, Warner and Co.; Robert W. Stewart; Harold H. Swift, vice-president of Swift and Co.; Charles H. Thorne, late chairman of the Montgomery Ward Co.; Frank O. Wetmore, chairman of the First National Bank of Chicago; Leo F. Wormser, member of Rosenthal, Hamill and Wormser, Chicago.

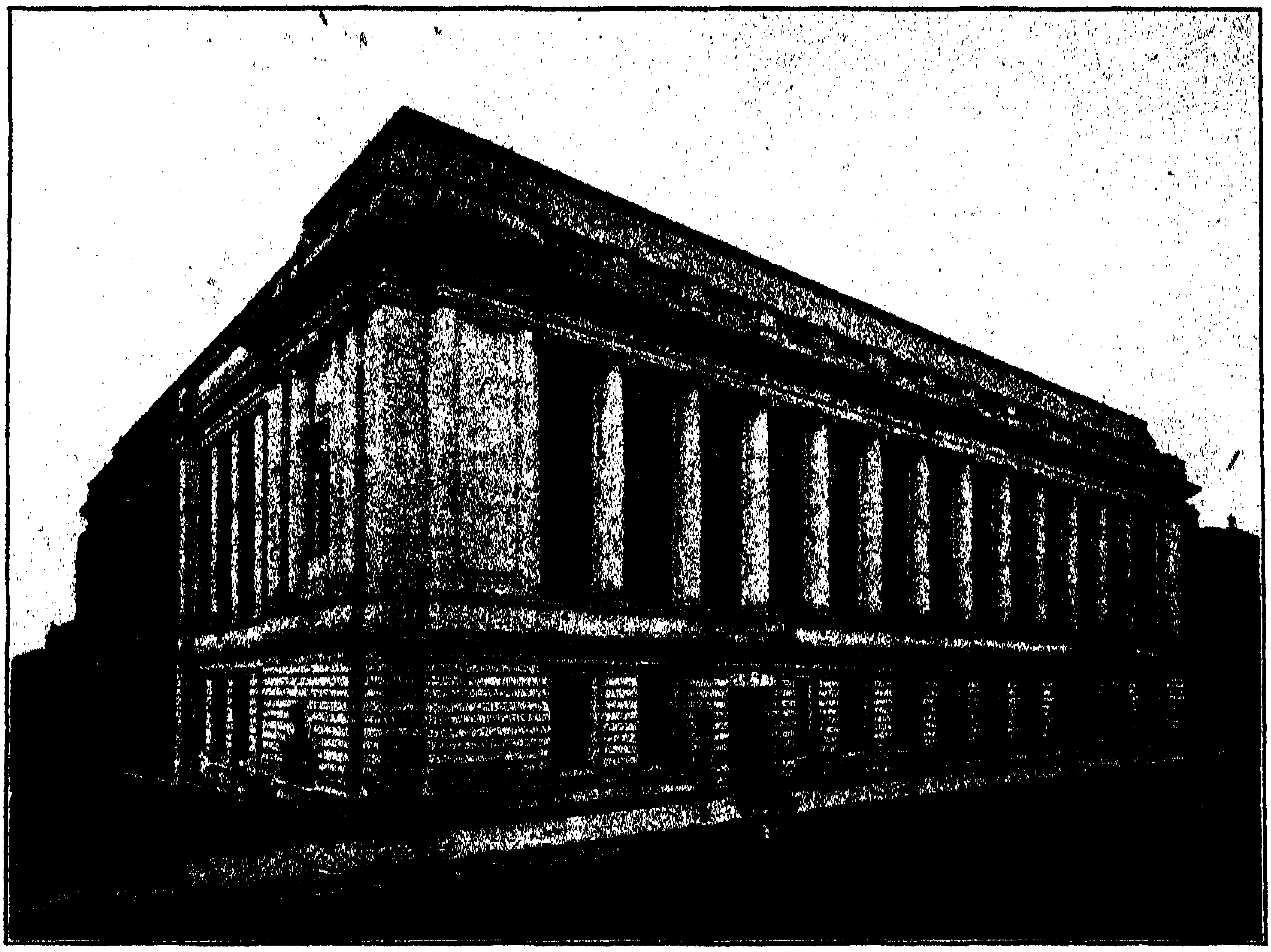


MUSEUM FÜR TECHNIK UND GEWERBE, VIENNA, AUSTRIA

As in Munich, historic locomotives will pant in the Rosenwald Industrial Museum as they panted a century ago to show how mechanical transportation on rails began. Later engines, also in motion, will reveal the strides that have been made in hauling heavier and heavier loads and in conveying passengers at higher and higher speeds and with greater comfort than Stephenson dreamed of in 1825. The beams of Newcomen engines will rock and show how cumbrously and inefficiently steam was applied before Watt's time, and the chasm between these obsolete titans and the modern silent, completely encased steam-turbine will be bridged by the inventions of Watt, Hornblower, Corliss and Parsons. Edison's Pearl Street power plant in New York will also be there in miniature—the first of the central stations that ushered in the electrical era of industry. And so will the telegraphs, telephones, radio-signaling devices, telescopes, plows, harvesters and the thousands of inventions without which modern civilization would seem empty. Why we can sit in our homes and listen to the strains of a violin played by a great artist a thousand miles away and wafted on invisible waves that pass mysteriously through mountains and houses as light passes through glass; why chemists have succeeded in synthesizing thousands of perfumes, dyes, flavors, explosives and healing drugs from the derivatives of coal-tar, a disgusting ooze once so much of an abomination that it could not be turned into streams lest it poison fish or be buried lest it kill vegetation—all this and more will be explained much after the European example.

Scientific principles and inventions are discovered and made to be utilized. What do they mean in our lives? It is this question that the Rosenwald Industrial Museum intends to answer as well as to explain science and industry technologically. In Munich a student learns more sound engineering in half a day by watching an engine turn a crankshaft than he can learn in a week by studying the diagrams and descriptions in a text-book. In Chicago he will supplement technical knowledge similarly acquired by learning from three-dimensional models, pictures and films what effect the engine had on the society of which he is a member.

It was Herbert Spencer who first pointed out that instruments and machines are but extensions of the human organs, and it is thus that many of them must be interpreted if their social significance is to be fully grasped. What is a steam-actuated, organ-peel bucket but a huge steel hand which clutches five tons of ore or coal instead of five ounces? What is any gantry crane but a gigantic system of steel muscles controlled by the living brain and the hand of an intelligent workman whose chief exertion is the closing and opening of a switch? Telescopes and microscopes—what are they but amplifications of the human eye? The historian Fairgreave has driven home the social meaning of these extensions of the human body by strikingly contrasting the society of ancient Greece with that of New York and of Chicago or London in terms of man-power. In the time of Pericles a Greek freeman commanded the services of five helots or slaves—the equivalent of about half a horse-power; and the best grain mill in the heyday of Athens produced roughly the equivalent of five barrels of flour a day. Over ten years ago Gilbert and Pogue estimated that the average free-born American of our time has at least thirty slaves at his beck and call in the form of machines, an estimate which has since been doubled by others. A good modern grain mill produces at least 20,000 barrels of flour a day. In a steel mill or an automobile factory a single worker may control ten thousand horse-power. Brains have become more important than muscles. Suppose that



—*Courtesy of the Science Museum*

SCIENCE MUSEUM, SOUTH KENSINGTON, LONDON

we were to sweep away these automata and that we were compelled to produce the goods we consume at prevailing costs by harnessing human energy to swing hammers that weigh tons and to lift ladles that contain small lakes of liquid steel. The United States alone would have to support a population at least sixty times greater than it is, if the average American is to maintain himself in what he has come to consider economic decency and comfort. Thus we are enabled to picture in imagination the social and economic consequences that have attended the introduction and evolution of industrial processes. And thus it is that the Rosenwald Industrial Museum will undertake to interpret the machine.

The populations, mostly slaves, that western countries would have to sustain to produce with man-power alone the goods now consumed raises a question. How would these human swarms be fed? And that in turn makes us consider how the civilized world feeds itself to-day, numerically stronger now than it ever was. The truth is that even the nations of this machine age would starve were it not for the aid of science and engineering—starve for lack of chemical fertilizers and mechanical plows, sowers and reapers, for lack of steamships and railway trains, for lack of methods whereby foods may be preserved so that the plenty of fat years may be enjoyed in the lean. We see, then, what a dominant rôle agriculture, the packing industry and the preservation of foods by refrigeration and canning processes, industries of which Chicago may be regarded as the capital, must play in the Rosenwald Industrial Museum. So the thousands of visitors who will pass in and out of the museum in the course of a month will acquire a vivid sense of what engineering and natural resources mean in their own lives. The harvester

and reaper, locomotives and steamships will cease to be merely ingenious combinations of machine elements and become saviors of the human race.

Intimately connected with this feeding of the world is the problem of keeping it in health—of staving off disease. The introduction of the steam-engine gave us the factory and mass production, and the steam-engine in turn made it necessary to huddle masses of humanity in industrial centers. Social problems were presented which could be solved only by science. Without its aid tuberculosis and typhoid fever would make it impossible to house workers decently or to provide them with the clean, well-lighted factories and offices in which they now work. The bacteriologist and the sanitary engineer are doctors of civilization. In that section of the Rosenwald Industrial Museum which will be devoted to the evolution of the industrial city, water-pipes and drainage systems, stepped-back skyscrapers and smoke-consumers will therefore appear not alone as interesting applications of science but as the means whereby an industrial society is enabled to work and clothe and feed itself without committing suicide.

Similarly, chemistry will be presented both as a technical aid and as a social and economic force. We are now passing almost unconsciously through a chemical revolution. In the Rosenwald Industrial Museum we shall see the chemist not only mimicking nature in the factory but tearing matter apart and reassembling its constituent atoms into compounds unknown in nature. It is not enough to trace thousands of drugs, perfumes, flavors, photographic developers and explosives back to coal-tar. We must also connect coal-tar with the industrial rise of modern Germany. Nor can we ignore its effect in strangling the indigo industry of India or the madder-root industry of southern France which latter was responsible for the turkey-red with which the trousers of the French soldiers were once dyed.

As soon as the social implications of science, engineering and industry are thus developed the museum visitor realizes that the nature of technological research is often determined by the conditions under which men live. That necessity is the mother of invention has been thoroughly disproved by Professor Taussig, who finds that most of the great inventors were urged by what McDougall calls the "instinct of contrivance." But how this instinct shall manifest itself is determined by the social and economic pressure of the time. In this respect invention is like art. Jazz and futuristic painting could not have appeared in Lorenzo di Medici's time, nor could the dynamo and radio, simply because the proper cultural and technical heritage were lacking. This means that while Edisons "happen" as do Michelangelos they are stimulated by the artificial environment that their predecessors have created.

The steam-engine, for example, was not wholly the result of a happy technical inspiration. Even those who know something of the history of technology are not all aware that as early as the reign of Queen Elizabeth England's forests had been hewn down, and that Englishmen were more or less dependent on coal as a household and industrial fuel. The coal mines, mere open pits for the most part, were drowned, and the horse-pumps of the time were unable to drain them. By the early eighteenth century the situation was critical. A great invention, some mechanical substitute for the horse, was needed. The economic pressure acted on the brains of dozens, perhaps hundreds, of engineers for at least a century. Two engineers, Newcomen and Savery, proved equal to the task of devising a steam-pump which would surpass the horse as an engine.

Surely it becomes a duty on the part of the Rosenwald Industrial Museum to

SIXTEENTH CENTURY ALCHEMICAL LABORATORY IN THE DEUTSCHES MUSEUM

dramatize the story of this social and economic pressure. But how? The methods are various. Imagine a diorama in which as many as five hundred horses are shown hopelessly struggling with the rising water of a drowned mine. In the neighborhood, smithies and primitive workshops stand idle for lack of fuel, and peasants shiver in their huts. Imagine, too, a suitably worded label which will amplify what little is not self-evident in this staging of England's plight. Perhaps a few statistics may also be required to drive home the full significance of the scene, especially for the university student of economics. We picture a crisis, a situation which can be surmounted only by a highly inventive engineer. We are then ready to study the surmounting means—the Newcomen-Savery engine in which steam is crudely and wastefully condensed within the cylinder itself by means of cold water, so that atmospheric pressure can drive the piston down.

The next step is, of course, the invention of the separate condenser by James Watt, instrument-maker to the University of Glasgow. His technical and social relation to the past is now clear. We see at once how utterly impossible it was for him to have given the world the steam-engine that bears his name without the structure of Newcomen and Savery to build upon. Then follows the most extraordinary social and economic transformation that the world has ever seen—what economists call the "industrial revolution." The museum will depict what it meant to place mechanical energy at the disposal of industry. Coal becomes an even more precious natural resource. Henceforth it is energy. Charts will show how coal mines were opened in every civilized country, how great industrial cities sprang up near coal mines, how social problems were created in these industrial centers that only the combined resources of bacteriology, medicine and engineering could solve. The visitor who leaves the museum will come away with the impression that James Watt was something more than a great inventor—that he did more to transform the face of the earth and mold social institutions than Alexander the Great, Julius Caesar and Napoleon Bonaparte, and that history is made in the laboratory and workshop as well as on the battlefield.

When we thus consider the social implications of the engineer's work the real meaning of this dawning electrical age becomes apparent. To be sure, the rise of electricity from Thales to Thomas A. Edison must be traced technically if for no other reason than to show that for centuries electricity was of no social and economic importance. There will probably be a reproduction of the famous laboratory in which Sir Humphry Davy and Michael Faraday conducted their classic researches, and the visitor will perhaps imagine that he is himself Faraday when he performs the very experiments that enabled the greatest of experimenters to lay the foundations of modern electrical engineering. A new social world will be revealed to him when the visitor sees what Morse, Bell, Edison, Siemens and Marconi accomplished with discoveries that seemed to have but a purely scientific worth at the time that they were made. Energy is no longer localized by coal. It is shot hither and thither along wires and sent rippling through empty space itself. The visitor will understand the significance of the transition period through which we are now passing, a period in which electrical energy generated by twenty and even fifty central stations located in a dozen states is pooled to form a great invisible reservoir which may be tapped at will, so that an excess in one city may make good a deficiency in another. Three-dimensional models, some of which will move incessantly, will make it clear to him that our industrial centers are

DISTILLING APPARATUS IN THE DEUTSCHES MUSEUM

already beginning to disintegrate, that factories are being slowly transferred from overcrowded cities to regions where land is cheap, labor abundant and electrical energy available. He will become aware of the fact that he is participating in an electrical revolution and that, like James Watt, the electrical engineer is molding society and rearranging the economic and social structure.

One after another the great inventions and discoveries will thus be taken up, first to be explained technically and then to be socially and economically integrated with their time. Hence we must not be content with a working model of the first Otis elevator. We must also show how that elevator made possible the Chicago and New York that we know, cities with structures towering to heights that still seem incredible to many a European. Perhaps we shall show the vast area that Chicago would have to cover if its office buildings were but five stories high. Certainly the museum must

present the social problems that the skyscraper, the direct result of the elevator, has created—present, for example, the spectacle of fifteen and even twenty thousand people, the population of a small town, discharged from a single building upon the street at the end of a working day, and then connect these hordes with elevated railways, subways, trolley-cars and omnibuses. In other words, the elevator, the tall office building, hotel and apartment house, subways and street-railways are socially related to one another, and this organic relationship must be brought out by models, paintings, motion pictures and dioramas.

Similarly the cotton-gin becomes more than the simple mechanism that it is. We shall see it in the Rosenwald Industrial Museum changing the entire primitive character of the south, creating a demand for labor which was met by the importation of slaves, and thus confronting us with a social problem, in this case a racial problem, which is not yet completely solved.

One of the most interesting halls will be that devoted to what may be called the news of science and technology. If a few centuries hence one of our descendants were called upon to write a history of the United States on the basis of the news published in the American papers of our time the picture that he would form of life in the early twentieth century would surely be distorted. Only the advertisements would save him from concluding that it was almost impossible to venture abroad without being robbed, assaulted or murdered, that public officials were usually corrupt and that our private lives were scandalous. Since we gossip in print chiefly about death and destruction the great technical accomplishments of our scientists, the important news of the day, receive short shrift. The Rosenwald Industrial Museum has no intention of competing with the press, but its officers conceive it to be one of their principal tasks to show how the pioneers of science, engineering and industry are pushing on and establishing new frontiers.

Pure speculation will play no part in the Rosenwald Industrial Museum, and yet the people of Chicago will catch some glimpses of the technical future as they wander through this new hall devoted to proposals which are practical and which are therefore being seriously considered by states, municipalities and corporations. Of late we have heard much of the English Channel tunnel, for example. Few engineers will deny the feasibility of stepping on a train in London, of traveling under the channel at a speed of sixty miles an hour and alighting in Paris a few hours later. If the Rosenwald Industrial Museum were now in existence there would be a model of that tunnel in the hall devoted to Concepts of the Day, so that Chicago might see how the engineer would make intercourse between France and England easier. Television has become a reality. If that hall were in existence we would display in it a model to make the underlying principle plain and to forecast such social effects as the possibility of producing a play in Chicago and of seeing it and hearing it, with the aid of the loud speaker, in every important city from San Francisco to New York. Or if chemists have discovered (as Berthelot did some twenty years ago) that sugars need not necessarily be squeezed out of canes and roots but that they may be some day commercially synthesized out of familiar gases, the museum will make it possible with the aid of appropriate models exhibited in that hall to understand the nature of the process and to accept it as perhaps the beginning of an era when at least some of our foods will be produced by juggling atoms in a factory rather than by sowing and reaping. In a word, that special hall will be a place where the news of the laboratory will be concretely expressed in models. In

REPLICA OF JAMES WATT'S FIRST STEAM ENGINE IN THE DEUTSCHES MUSEUM

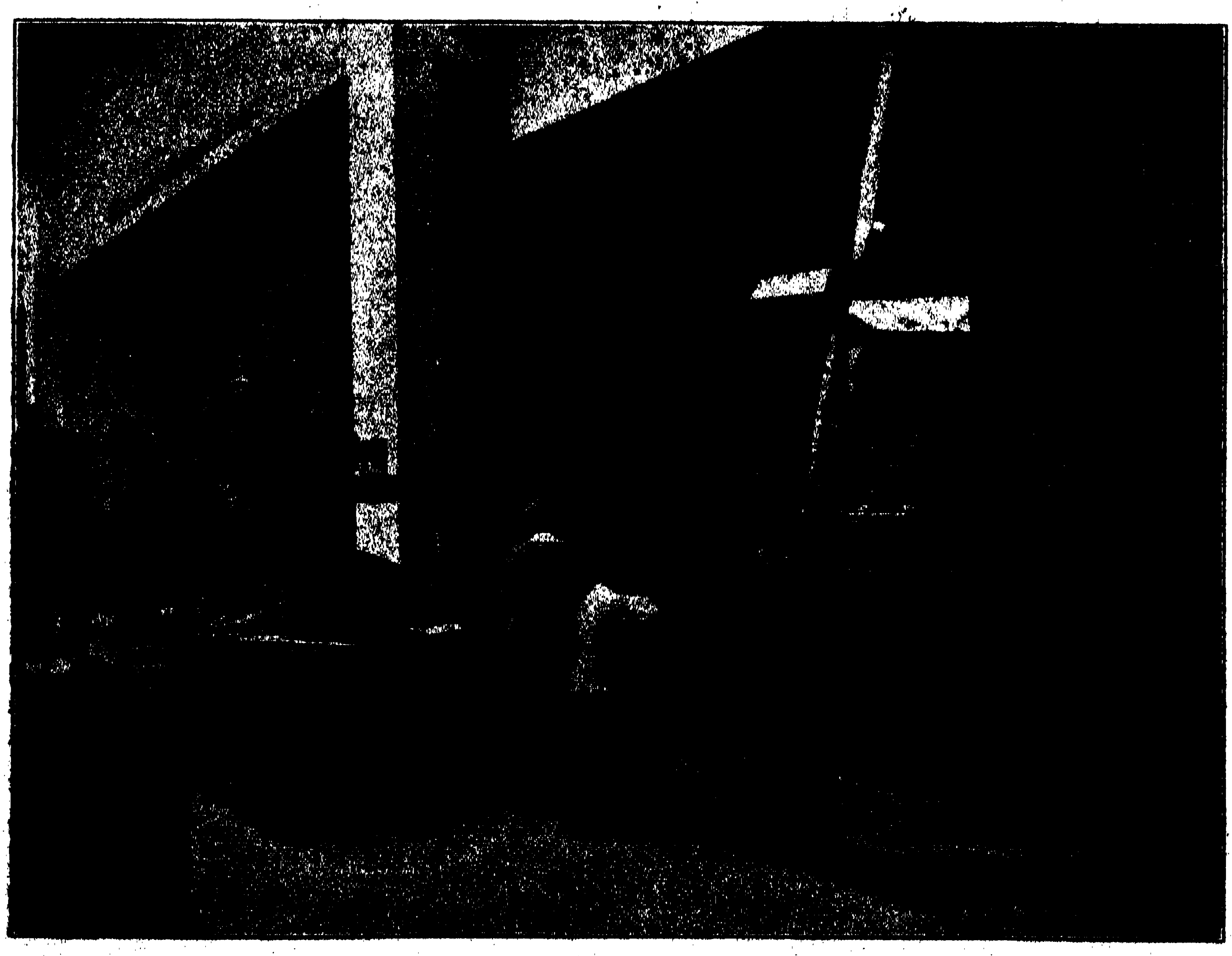
no existing technical museum is such a hall to be found. Science, engineering and industry are not stagnant. In Chicago their vitality and growth will not be ignored.

In a museum which addresses itself to the task of interpreting technology socially the scientist, engineer or inventor will cease to be the familiar "wizard" of the newspapers and will assume a new but less deceptive glamour. His indebtedness to tradition and to the stimulus of his time will become apparent. His genius will never be questioned, but the technical heritage of the race will be correctly appreciated. The public will see for itself that motion pictures, radio broadcasting and television are the products of a long evolution, for the individual steps will be displayed in the museum. As he wanders literally through centuries of human technical and social progress in the Rosenwald Industrial Museum, as he sees how the technical mind has developed such remarkable primitive inventions as the wheel and the sail the visitor will realize how much great scientists, engineers and inventors owe to the sheer momentum of the past. He will also see how one science has borrowed from another, how the metallurgist, for example, has imbibed the principles of chemistry until he has become a chemist himself, how the laws of Newton, once regarded as purely theoretical expressions of relationships of masses to one another, have become the foundation stones of physics and engineering. Hence the labels that will be affixed to the exhibits will place the inventions where they belong in what patent lawyers call "the state of the art." No invention is original in the sense that there was nothing quite like it before or in the sense that its elements are individually new. It is an accretion that may be hundreds and even thousands of years old. One of the principal tasks of the Rosenwald Museum will therefore be that of revealing the tech-

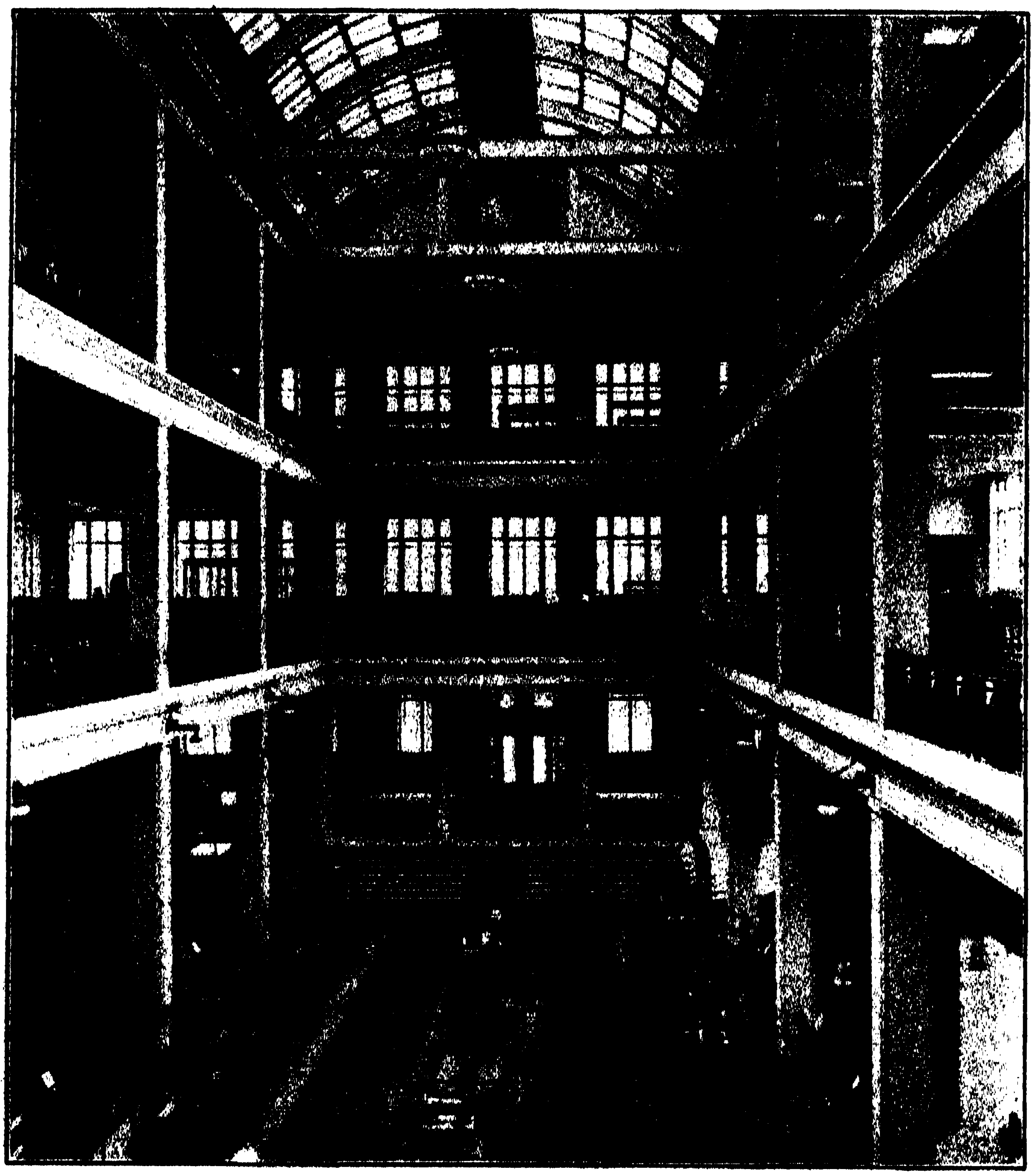
nical heritage, the manner in which one principle is combined with another until at last by patient scientific research and by a supreme effort of synthesis we find the Wright brothers, for example, assembling elements which were in themselves familiar, almost miraculously presenting the world with the first successful, man-carrying flying-machine and thus ushering in a new era in transportation that is bound to have far-reaching social consequences.

This matter of awarding credit where credit is due becomes all the more difficult when we reach our own day. Organized research has become as essential an activity of industry as manufacturing and selling. Technical progress, no longer spasmodic and haphazard, is systematic and even predictable. The lone, heroic inventor probably belongs to the past. His place has been taken by groups of research physicists, chemists and engineers directed by a great leader in an industrial laboratory. Technical achievements are therefore rapidly becoming anonymous because they can not be credited to a single towering genius. Surely it is the task of the Rosenwald Industrial Museum not only to exhibit what has been invented in the past and in the present but also to explain how it was invented and to account for the velocity of the technical progress of our own time.

In any such consideration of the methods of invention and research the part played by the far-seeing business man can not be ignored. He has made research a social and an economic force. The heads of our great industrial corporations must be linked with Boulton, who made Watt what he became, with Cyrus Field, who typifies the daring and the understanding of our technical day better than any other figure, and with



WIND MOTORS IN THE DEUTSCHES MUSEUM



—*Courtesy of the Science Museum*

SCIENCE MUSEUM; MAIN HALL LOOKING EAST

Gardner Hubbard, who had as much to do with the success of the telephone as Alexander Graham Bell. No one can view the history of invention in the Rosenwald Industrial Museum without discovering that the inventors of old needed keepers and that the business man, so far from being a mere exploiter of technical genius, provided not only the capital but the inspiration and driving force without which we would have no railways and aeroplanes, telegraphs and telephones.

Every museum of to-day is primarily an educational institution. Hence museum technique has been profoundly affected by improvements in teaching methods. The successful teacher is usually he whose presentations are most vivid. So we find that both the classroom and the museum are livelier and more interesting than they were fifty years ago. The dramatic is introduced not for its own sake but as a means to an educational end, and this is as it should be because it is the primary function of the drama to interpret life. Since the Rosenwald Industrial Museum will explain not only the operative principles of the machines but the relation of the machines to life, it follows that it must count upon dramatic effects to achieve its purpose, but this without becoming theatrical.

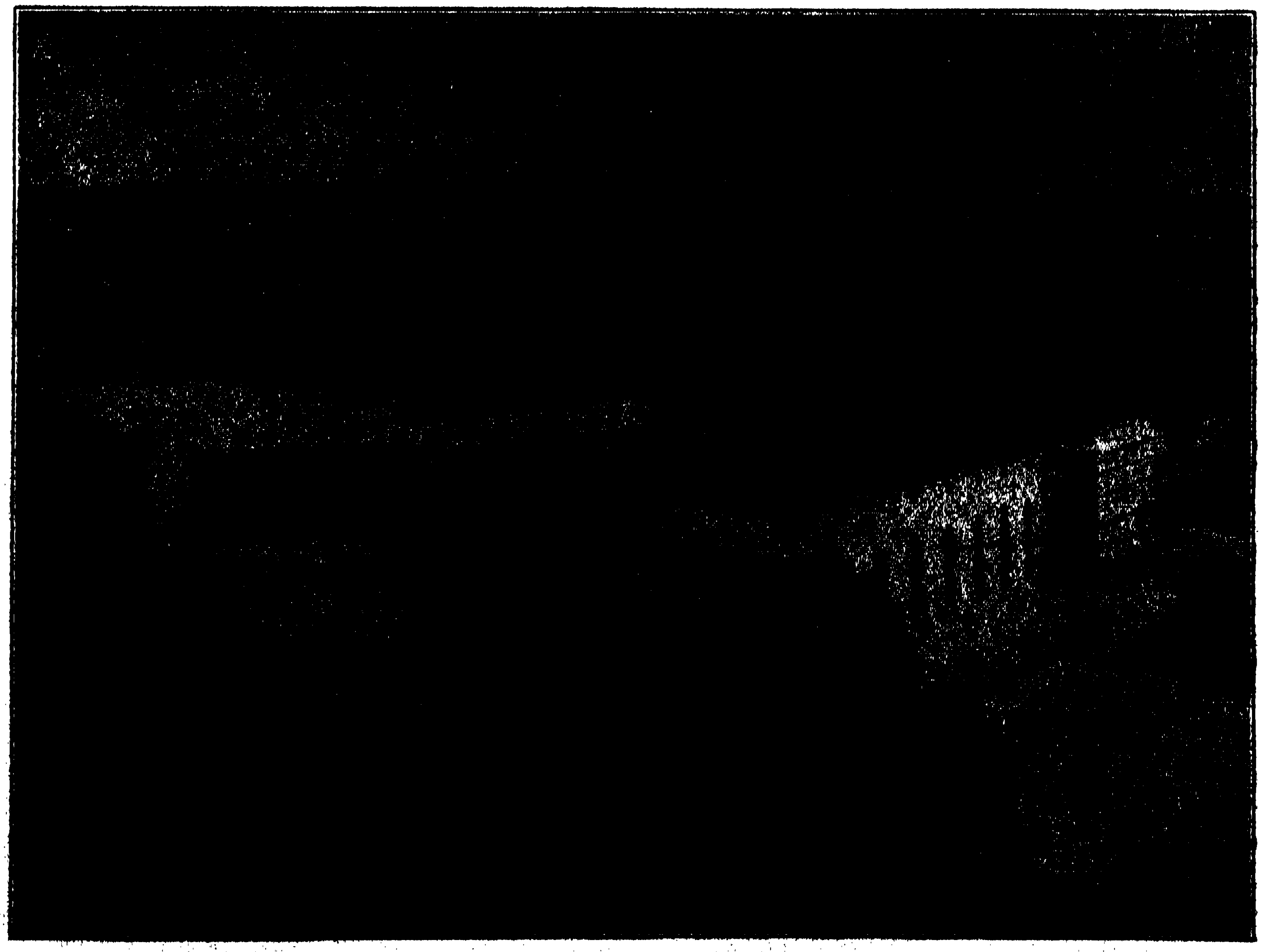
Let us take the road, for example. It is not enough to show how the Appian Way was built or what were the technical methods that made the roads of

Macadam and Telford what they were and still are. We must contrast the smooth, hard road of to-day with the knee-deep mud through which our colonial forefathers plowed their way. Read this from Brissot de Warville, a Frenchman who traveled from Philadelphia to Baltimore in 1788:

> From thence [Havre de Grace] to Baltimore are reckoned sixty miles. The road in general is frightful; it is over a clay soil, full of deep ruts, always in the midst of forests, frequently obstructed by trees overset by the wind, which obliged us to seek a new passage through the woods. I can not conceive why the stage does not often overset. Both the drivers and their horses discover great skill and dexterity, being accustomed to these roads.

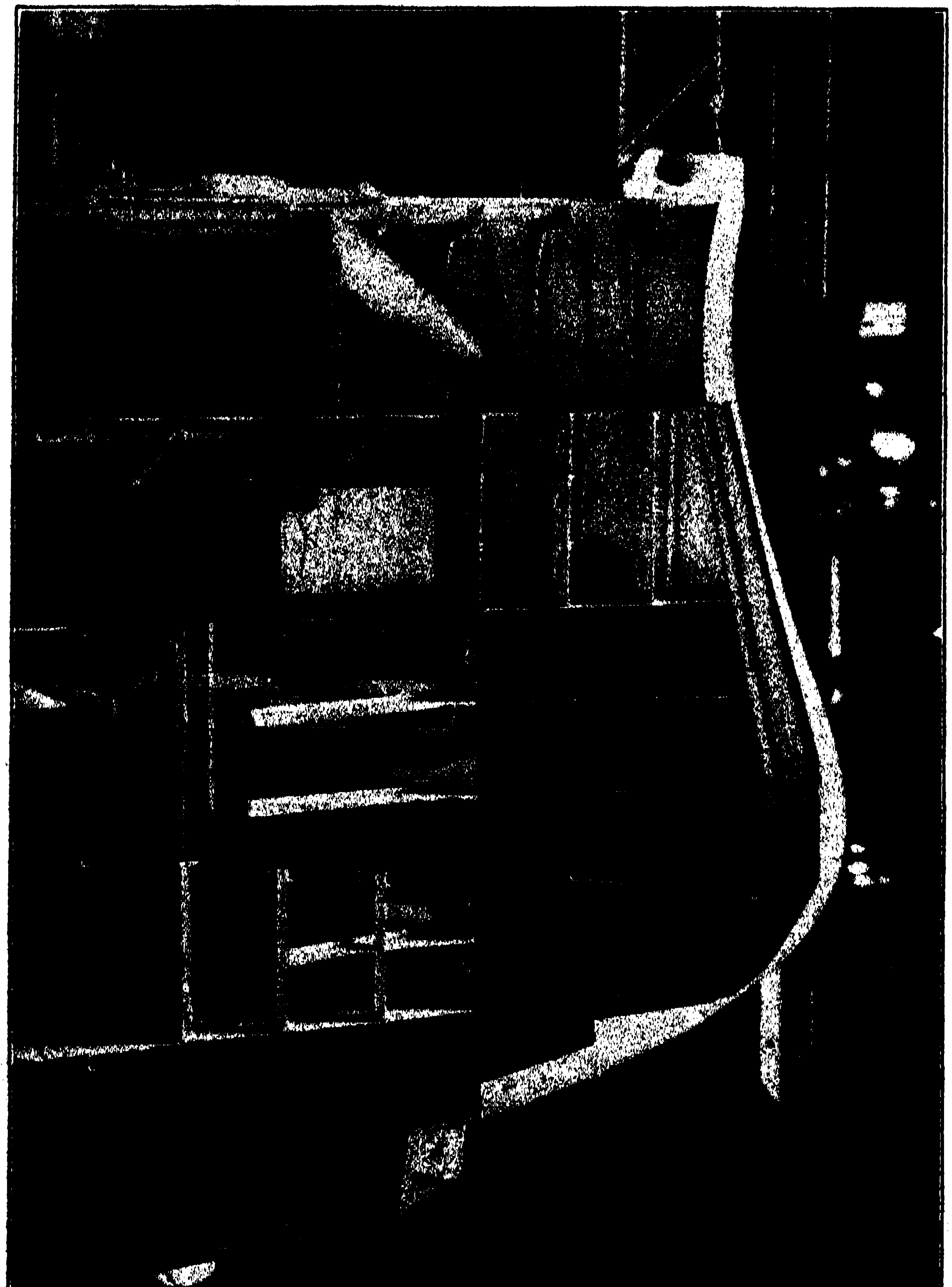
Add to this Lardner's statement that before the days of good roads and railways the charge for carriage by wagon between London and Leeds was at the rate of about $63.31 a ton, or twenty-seven cents per ton-mile, and we have material enough for an exhibit which will show how manufacturing was hampered and why such heavy materials as coal "could be available for commerce only where their position favored transport by sea." It is easy enough to imagine a diorama which will explain the difficulties of trading two hundred years ago and prepare the visitor for the railway and the enormous part that it played in the national and international growth of manufactures.

When it comes to tracing the evolution of railway rolling stock the museum will be faced with a difficulty. The policy of exhibiting full-sized machines has proved to be the best in Europe. Yet, despite its 400,000 square feet of floor space, the Rosenwald Industrial Museum is not large enough to contain every important railway vehicle from the first coach which was hauled on the Stockton and Darlington Railroad over a hun-



—*Courtesy of Deutsches Museum*

DIORAMA OF THE ISAR HYDROELECTRIC PLANT



BOW OF THE BATTLESHIP "RHEINLAND" IN THE DEUTSCHES MUSEUM

dred years ago and which bears all the evidence of its horse ancestry, to the modern, steel Pullman sleeper. So the Rosenwald Industrial Museum must telescope time and space. A car will be constructed which will be divided into periods. In the first compartment you may seat yourself, and experience all the sensations of bumping over the poorly ballasted and none-too-well-laid rail of the forties; for that compartment will be mechanically shaken to impart the realities of a railway journey in the days of our grandfathers. As you look out of the window you see the landscape of the time—a realistic painting, ingeniously illuminated, traveling endlessly on rollers. The last compartment will be that of a modern Pullman sleeper. Its motion will be hardly perceptible, and from the windows the painted skyscrapers of Chicago will be visible.

It is likewise impossible to trace the development of pavements, water supply and sewage disposal with full-sized reproductions of streets. And so in the

Rosenwald Industrial Museum there will be a street which will be easily ninety feet long and which will be divided into periods of time. In two minutes the visitor will walk from the seventeenth century to the twentieth. He will see a gentleman of Elizabethan London carried in a chair through the mud with link-boys to light his way home; he will note the absence of an adequate water-supply and drainage system. As he steps into the next division it will strike him that oil lamps illuminate the darkness and that footway and carriageway have improved. And so, as he walks on, he will be impressed with the change wrought by the introduction of gas and electricity, of water and sewer mains and of better houses, all bearing an obvious technical relation to the improved street. Finally he enters a few feet of Michigan Avenue of to-day, with shop windows and streets brilliantly illuminated, with the hard, smooth asphalt beneath his feet, and a roadway honeycombed with conduits for cables that deliver energy or convey messages.

The temperament and mental needs of America are different from those of Europe. Accordingly, the Rosenwald Industrial Museum must evolve its own methods in an effort to keep pace with the rapid transitions of America. The motion picture, for example, still plays a minor rôle in Europe, partly for lack of funds and partly for lack of a sturdy and faultless daylight projector. In the Rosenwald Industrial Museum scores of motion-picture machines will be found, operated for the most part by push-buttons. It will be their function to clarify the obscurities of radio and X-rays, the Einstein theory of relativity and the wheeling of the planets. With their aid the public will be photographically transported into steel mills and factories to learn how the principles elucidated by moving models have been industrially applied. Some of the films will talk in sound-proof booths and thus relieve attendants of much lecturing.

The wax manikin is still inevitable. Yet in Chicago the experiment will be made, at first on a small scale because of the expense involved, of substituting here and there living flesh and blood for wax. If we are to show how life has been affected it should be with the aid of life itself. In an auditorium in which distinguished sociologists, economists, scientists and engineers will deliver popular lectures an opportunity will be presented to test the possibilities of this innovation in museum technique. If a distinguished anthropologist lectures on primitive inventions he will be assisted, if need be, by skilled and suitably costumed pantomimists who, amid proper surroundings, will live over again the precarious lives led by huntsmen forty thousand years ago or give us a vivid glimpse of what existence must have been among the Swiss pile-dwellers. So, too, the possibilities of some new invention, such as television, may be disclosed with an effectiveness that can not be attained even by the motion picture.

Pure science being the basis of modern industry, it follows that its achievements from remote antiquity to our own time must be presented simply and arrestingly. Again the visitor will be asked to consider more than a collection of historic apparatus and to teach himself the principles of physics and chemistry. He will learn what hitherto he could learn only out of books, what is not taught in any European technical museum and yet what is psychologically of the utmost importance in understanding why more technical improvements are now made in a decade than were once made in centuries—learn how we came to assume the objective attitude toward nature. The "industrial revolution" was brought about not only by wise patent laws and the steam engine but by the impersonal investigations of the scientist. That the student of natural science refuses to permit his personal beliefs and opinions to sway the course of his experimenting, and that he should

study a precipitate in a test-tube, a flash of lightning or an electromagnetic storm on the sun with complete detachment is something new—something scarcely more than two centuries old. He will learn, too, that Einstein's startling achievement is primarily due to a still further separation of the human personality from the thing or the event that it studies and that what we call "common sense" changes as science advances. So the cultural value of scientific research will be explained to the end that its true relation to modern industry will become more apparent.

The need of an educational institution such as the Rosenwald Industrial Museum is apparent. Edison and Westinghouse had to acquire their technical knowledge as best they could at a time when there were few, if any, engineering schools in this country. Imagine, then, the mental stimulus that future Edisons and Westinghouses will receive from such an institution as the Rosenwald Industrial Museum. Many a lad is bound to discover that engineering is his true bent. The advanced engineer and the student of industry will likewise profit by an examination of the museum's collections. Science, engineering and industry are so complex in their interrelationship that it is difficult to grasp the causes and significance of their rapid progress. Time was when even those who were not themselves artisans had at least an elementary knowledge of the leading arts and crafts. Horses were shod in a smithy with wide open doors. In this day of the automobile few of the younger generation have ever seen the process of its manufacture. Baking and laundering are now the business of great companies who have reduced them to chemical control. Houses are of necessity still built in the open, but the window frames and posts are delivered ready made from the mill so that the carpenter does little sawing and planing and is reduced to the status of an assembler of delivered lumber. Nearly all metal is fashioned in distant mills, and as a consequence only engineers know how rails, girders and other structural shapes are produced. The factory and the machine have so far usurped the place of the old-time craftsman that nearly all technical processes, from the making of a tin-whistle to the building of a locomotive, are now carried on with the aid of massive machines which are mysteries because they are rarely seen by the public. The enormous influence that the scientist has had on industry is but vaguely understood. As for the social effects that follow the introduction of new machines and processes, we are aware of them but we do not grasp their deep significance.

The principles of science are not yet the possession of the many even though the age is essentially scientific, and the effect of scientific research, invention and industrial progress is felt rather than understood. When Giotto finished a picture all Florence was jubilant and stopped work to celebrate the completion of a masterpiece which was not only a thing of beauty but which expressed the emotions of an art-loving city, all of which was as it should have been, at a time when art was scarcely less important than religion in the life of Italy. Science has usurped the place of art. It is perhaps asking too much that a city declare a holiday and rejoice at the discovery of the X-rays, but it is not too much to expect an intelligent public to discover what the rays mean to mankind as they find wider and wider application. There is no lack of interest in technology, as the small crowds testify that are fascinated by the stiff but efficient movements of a steam-shovel excavating a huge hole on the site of some future office building. But the people have no opportunity to gratify that interest, no opportunity to survey the technical and social progress of the past and evaluate the status of the present. And it is the primary purpose of the Rosenwald Industrial Museum to create that opportunity.

MAN'S INFLUENCE ON INSECTS

By Professor E. O. ESSIG

UNIVERSITY OF CALIFORNIA

THE dominance of man in this age of the world is evident in many respects. That he now effectually rules the land, air and water can not be denied. That he has at least partly subjugated other living forms may be admitted. In the botanical world he has apparent control of many domesticated plants which furnish food, including cereals, root crops, forage crops, nuts and fruits. He has also been responsible for the total destruction of great forests of temperate regions and thereby has greatly changed the botanical features of huge expanses, which show no immediate promises of returning to their original conditions. Likewise he has dominion over such animals as he has been able, through long ages, to domesticate and make subservient to his will. The cattle, sheep, goats, horses, dogs, cats and fowls are none of them likely ever to return to their original state of wild life, although all of them might be capable of doing so if man were entirely eliminated from the earth. Wild animals, not desired for domestication, have been ruthlessly destroyed to furnish food, clothing, ornaments, sport or wealth. Thus have almost completely disappeared the sea-otter, sperm whale, American bison, carrier pigeon, white egret, beaver, antelope and other animals. Only stringent game laws and game refuges are staying the wave of such destruction in all parts of the world. Africa, with its untold wealth of big game, would otherwise be stripped in a single generation by wanton men, who facetiously call themselves "sportsmen."

These, I think, are sufficient examples of man's power over certain types of living organisms. But the story is not yet concluded. In the world of minute organisms what has been done to subjugate the millions of pestiferous bacteria and protozoans, some of which cause man to appear helpless enough at times? And the fungous diseases which continue to cut down his food supply? Has he been able to materially affect any of these in a manner so as to destroy, diminish or even adequately control the least of them? At best he can only temporarily stay their advances. Diseases caused by them have so far never ceased to harass the human race.

Now let us turn to the immediate subject at hand, the insect world. What has man done to stay effectually the claims of these tiny hordes to the supremacy of this age? As one casually surveys the field he is likely to agree with those who are already sounding the warnings against the perils of the ever-present and unrelenting hosts of insect pests. To these perils man has, through the ages, turned a deaf ear and a quizzical, ignorant mind. He has created wonderful inventions to protect himself from his much less offensive and more vulnerable neighbors and has so far completely failed to grasp the significance of the vastly greater importance of these small animals which torment him openly, carry and transmit diseases which have done him to death, which have destroyed his timber and his homes, his crops and domestic animals, and have left him no place on earth to set his foot unmolested! Rather it appears that he has allied himself with these, his worst enemies, in order the more quickly to bring about his own undoing. As

—*Photo by Division of Subtropical Fruits, Univ. California*

LARGE AREAS OF CONTIGUOUS CITRUS GROVES LIKE THE ABOVE HAVE CREATED CONDITIONS MAKING POSSIBLE SUCH DESTRUCTIVE INSECT PESTS AS THE VARIOUS SCALE INSECTS, THRIPS, MITES AND WHITE FLIES. IMMENSE SUMS OF MONEY ARE REQUIRED ANNUALLY TO STAY THEIR RAVAGES.

evidence of this he has failed to rid his own body and home of filthy disease, bearing and transmitting lice, fleas and bedbugs. Throughout the ages these insects have sucked out his life's blood, have tormented him and have rewarded their sustenance with disease and death. The toll of typhus and trench fever in the great war and the common occurrence of all these and many other insects everywhere to-day indicate something of the composure and lack of concern of our race.

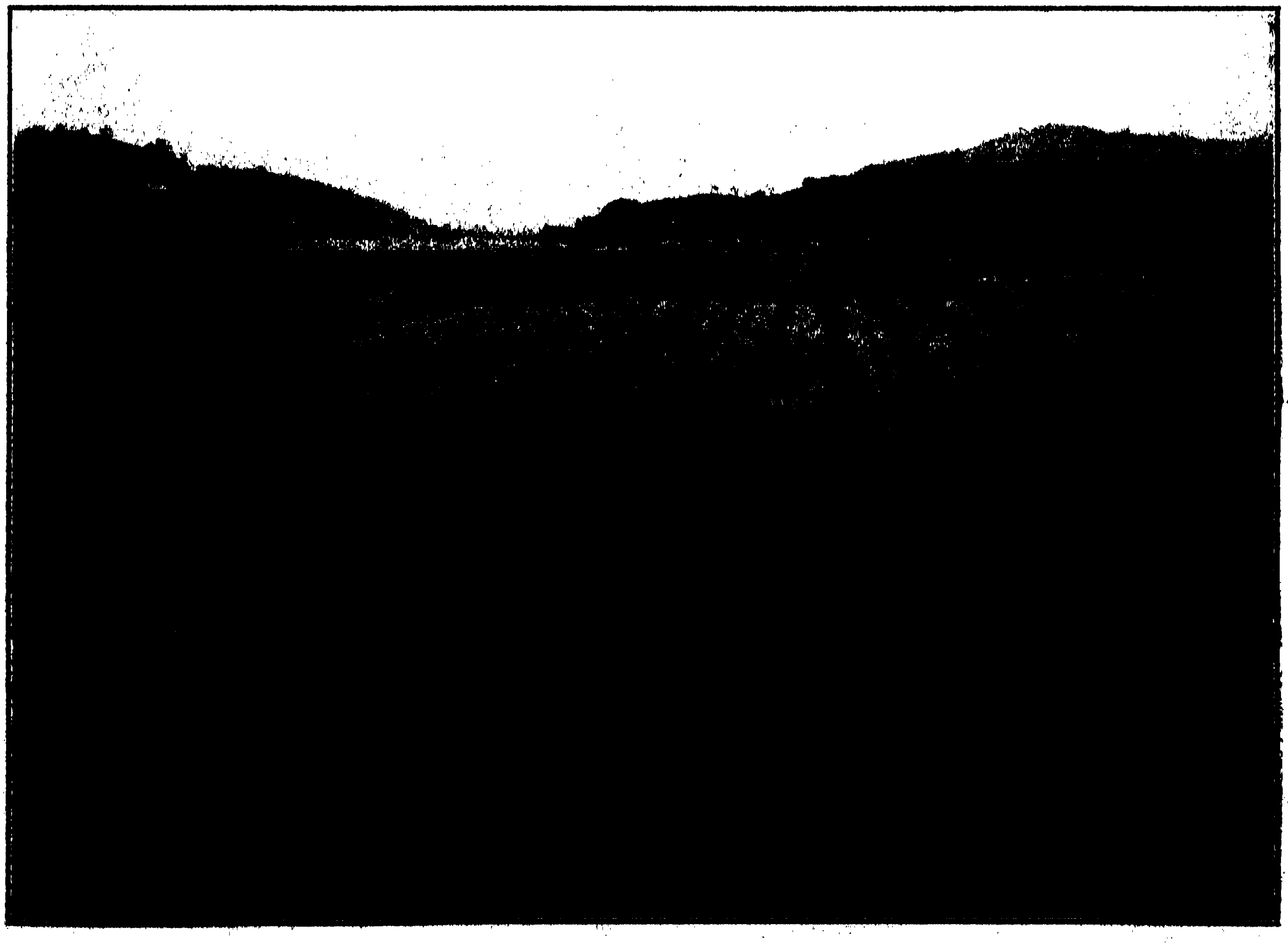
But this is only the beginning of the story. Man has not been wise enough to leave his tormentors behind him! He has taken them with him wherever he has traveled; he has sent them to the four corners of the world, and exchanged them with other countries by means of his commerce. Malaria, bubonic plague, anthrax, cholera, dysentery and yellow fever constantly knock at our doors and too often gain admittance. Which of the insects responsible for any of these has been greatly influenced by man? Malaria mosquitoes are suggestive and yet can any one hopefully argue that they are actually fewer in numbers now than they were a thousand years ago? Does it not appear that they have increased through wider distribution and perhaps more special and favorable conditions brought about by man? That certain small areas have been made inhabitable through the efforts of our race, as for instance the Canal Zone, is no real indication of the world distribution and abundance of the particular insects involved.

Man's fight for equatorial South America and Africa has been due chiefly to the barriers raised by insects. That they can be conquered without gaining a wider distribution throughout the world is contrary to past experience. Everywhere the balance is on the side of the insect.

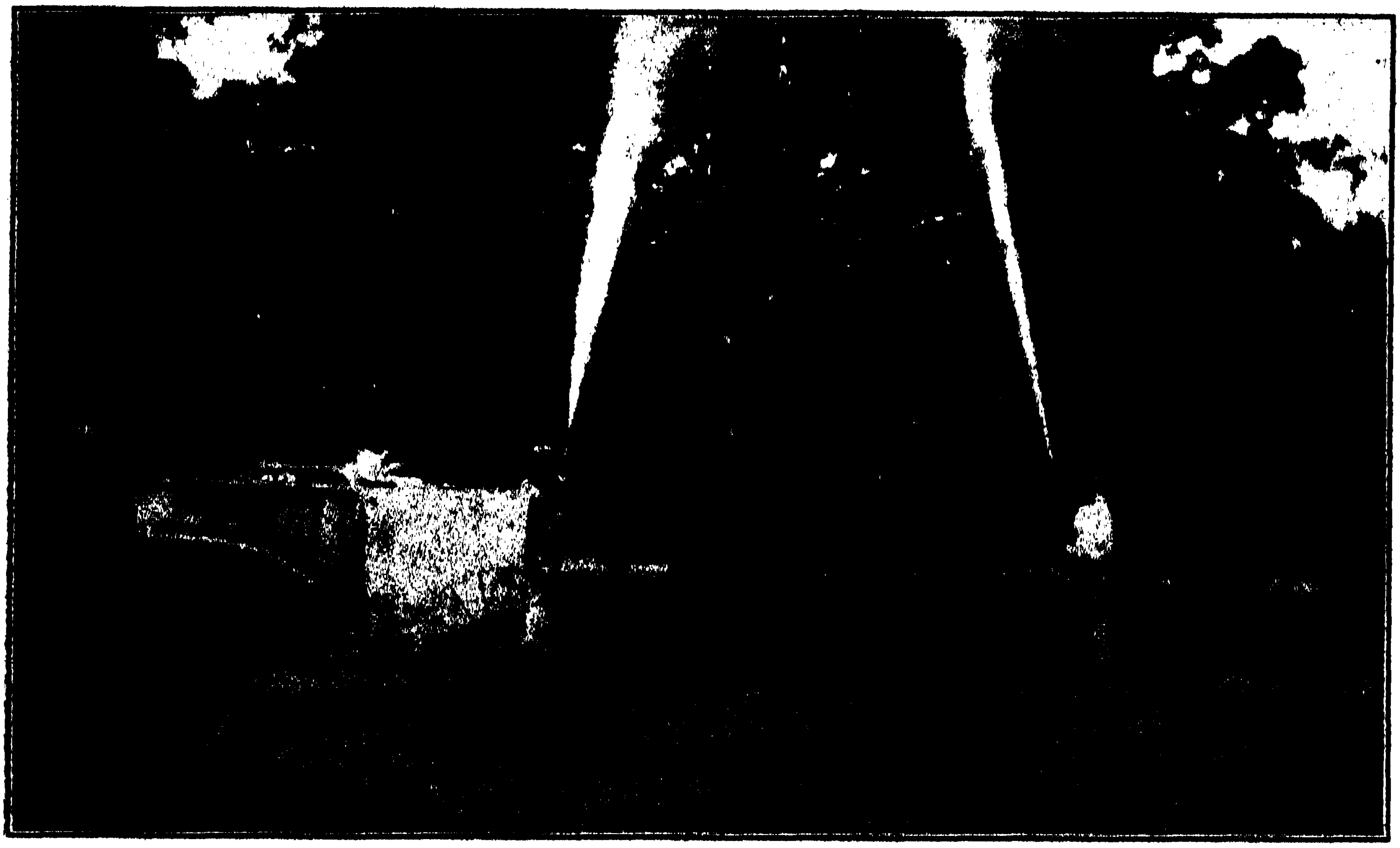
To the development of economic entomology in relation to agriculture we may look to find some glorious examples of vanquished insects. A note of encouragement may be sounded in the denuding of great forest areas and the destruction thereby of many serious forest pests. In this regard China has exchanged forest insects for famine-producing grasshoppers. In America the reclamation of the swamps and prairies has somewhat disturbed mosquitoes and grasshoppers, but the planting of huge continuous fields of wheat, corn, cotton, potatoes and orchards has created such pests as the chinch bug, Hessian fly, corn earworm, corn borer, cotton bollworm, Colorado potato bettle, San José scale and other insects unknown to man a few generations ago!

The cultivation and irrigation of the Great Basin has had a marked influence on stopping the migrations of locusts into Kansas and Nebraska—now they stay home! In many parts alfalfa has replaced buffalo pastures and the alfalfa weevil, an insect of little importance in southern Europe, becomes a Napoleon in this once semi-arid region.

In California we have almost within one generation built up a new and complete agriculture. Did we consider the



TO REPLACE THE NATIVE VEGETATION MAN HAS OFTEN SUBSTITUTED WELL-CARED-FOR ORCHARDS, WHICH INVARIABLY ATTRACT INSECTS FROM SURROUNDING AREAS. IN SUCH CASES THE INSECTS HAVE GREATLY BENEFITED BY THE SUBSTITUTION AND MANY NATIVE OR IMMIGRANT SPECIES HAVE THUS BECOME NOTORIOUS PESTS.



HIGH-POWERED SPRAYING MACHINES DISCHARGING POISONED LIQUIDS UNDER GREAT PRESSURE ARE USED TO PRESERVE A PORTION OF THE FRUIT AND NUT CROPS FROM THE RAVAGES OF CODLING MOTH, CURCULIOS, LEAF-ROLLERS, CANKERWORMS AND OTHER INSECTS.

insect problem in connection with our personal comfort and health? Did we consider our domestic animals and our food supply? Not at all! The day that the Spanish padres arrived in San Diego in 1769 they had with them an adequate number of pests to supply all their needs. The ships which immediately followed brought those lacking. In the earliest days our state became famous for its flies, fleas and weevils.

The history of some of our chief agricultural pests is interesting and right to the point. The Colorado potato beetle was one of our first insects to become a serious pest of a growing crop. It traveled backwards over man's advance from the Atlantic towards the Pacific. Man's continuous fields of nicely tended potatoes were far more to its advantage than the scrubby buffalo bur of the bleak mountain areas of the west. Since its first appearance in 1865 it has claimed all the cultivated areas of the United States and Canada with the exception of three western states; it invaded Germany in 1887 and reappeared in 1914; it was introduced into France in 1922, and now threatens the rest of Europe. It is a potential danger to potatoes wherever they are grown over the entire world. Its rise from obscurity and its present wide distribution are wholly due to activities of man. No amount of control measures has even suggested a restoration in numbers to its original state in the Rocky Mountains.

From obscurity in the wilds of North America the grape phylloxera, through commerce, was introduced into the vineyards of southern France some time prior to 1863. By 1884 it infested 2,500,000 acres, or half of all the vineyards in France, and in all destroyed at least three fourths of all the vines in that country. It was likewise brought into California, where it was discovered in 1873 and where it also did great damage to the imported European varieties of grapes. At least half of the vineyards

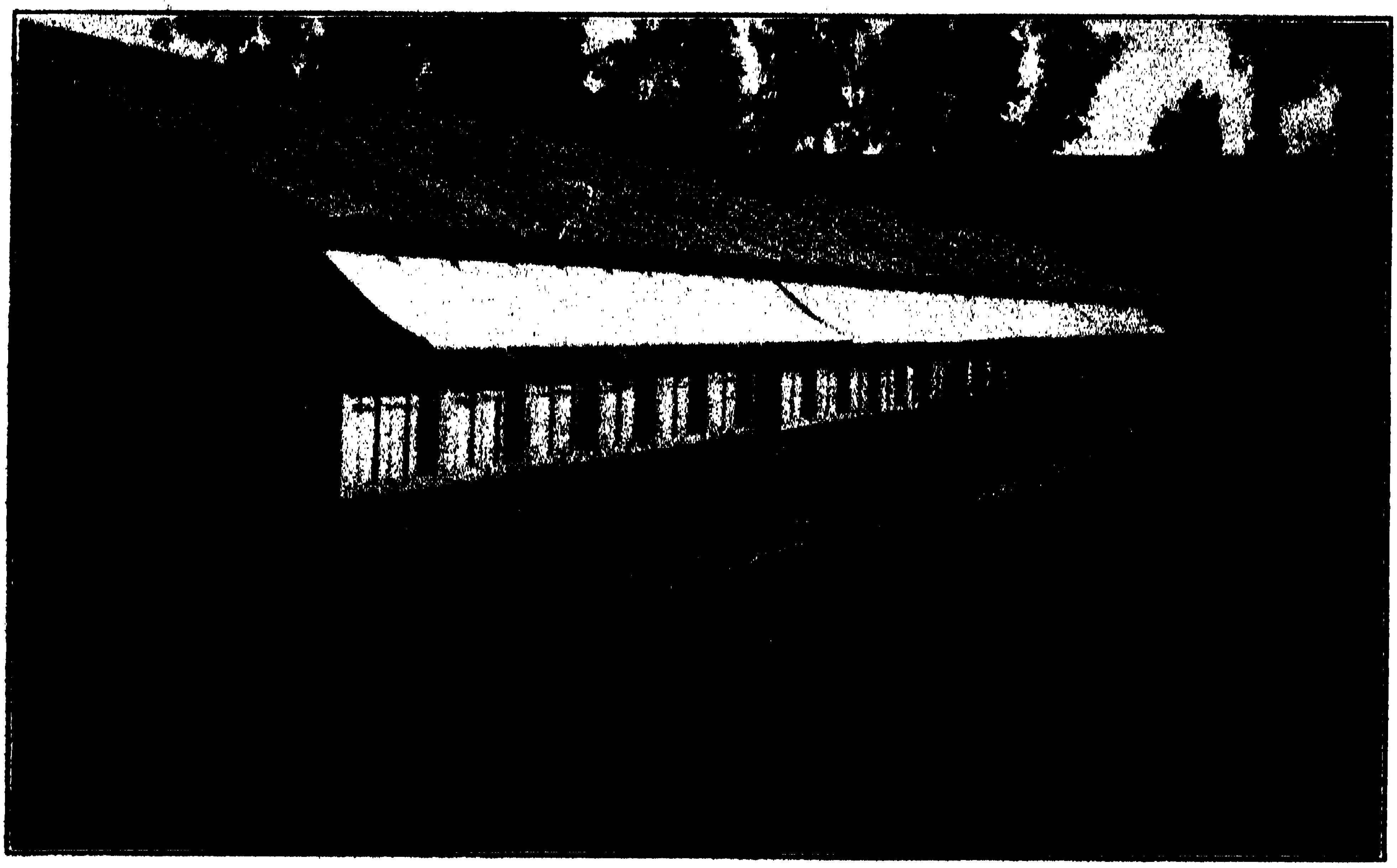
A STRING OF FUMIGATING TENTS IN AN ORANGE ORCHARD IN CALIFORNIA. LARGE AREAS OF EVERGREEN CITRUS TREES ARE IDEAL BREEDING PLACES FOR MANY INTRODUCED PESTS AND IT IS ONLY BY GREAT EXPENSE IN FIGHTING INSECTS THAT THE CITRUS GROWER IS ABLE TO PRODUCE PROFITABLE CROPS.

in France were reconstituted on resistant American rootstocks, while in California the pest was evaded by planting on new lands. Thus the phylloxera, through the direct intervention of man, has had its distribution and scope of food plants very greatly enlarged, while the control measures for its repression have only permitted the grapes to grow in spite of it, rather than eliminated it in any section.

—Photo by Bean Spray Pump Company

THE PEA APHIS ANNUALLY DESTROYS FROM TEN TO TWENTY-FIVE PER CENT. OF ALL CANNING AND MARKET PEAS IN THIS COUNTRY. THIS MODERN DUSTING MACHINE IS MAN'S METHOD OF DEALING WITH THE PEST.

The San José scale was introduced into California prior to 1873 by a prominent and wealthy citizen who admired the beauty of the Nipponese flowering fruit trees. In a few years it ravaged every deciduous fruit orchard throughout the United States and Canada, and not stopping here, has since spread to all the temperate regions of the world. It was not a scourge from heaven—it was simply one of the millions of species of insects, each with tremendous possibilities of increase and destruction, placed in the hands of an uninformed people! The codling-moth, the gipsy moth, the brown tail moth, the cottony cushion scale, black scale, red scale and scales of other hues, the cotton boll weevil, pink bollworm, the Japanese beetle, the granary weevil, rice weevil, vegetable weevil, Hessian fly, chinch bug, sugar-cane leafhopper, and, in fact, every serious insect pest has a similar history. Every one of them has had its distribution extended; its food supply enlarged; its activities increased and its numbers greatly multiplied by the intervention of man. I can think of no instance where a notable decrease in distribution or numbers from the original status of any insect has been brought about by the human race! Therefore, it appears that the entomological prophets of our times, who predict a winning contest for the insects, have some basis for their arguments.



INSECTARY CONSTRUCTED BY COOPERATIVE CITRUS FRUIT GROWERS IN SOUTHERN CALIFORNIA. HERE LADYBIRD BEETLES ARE REARED BY THE MILLIONS AND LIBERATED IN THE ORANGE ORCHARDS TO DESTROY THE DESTRUCTIVE MEALYBUGS.

There is still another point in this discussion that should not be overlooked. The insects have so far maintained themselves on this earth much longer than any other living type of higher animals, and very much longer than man. For this reason it may be assumed that insects are capable of withstanding a much greater variety of conditions than the human race. It is also fair to assume that as man acquires age and experience he will be much bet-

ter able to cope with insects and the smaller protozoans and bacteria.

For his very short space of existence man has shown phenomenal adaptability and ingenuity in dealing with his immediate problems of living quarters, food supply, health and general well-being. He has already eliminated many of the larger animals which were serious enemies and impediments to his early ancestors. Lions, tigers, wolves, bears and wild boars are now to be found mostly in zoological gardens and museums. The greatest task now ahead is to do the same with the destructive smaller forms of life. To me this task does not seem at all hopeless. Man's capacity for thinking, his inventive and creative powers appear unlimited. In but a few decades he has awakened somewhat to the real truth of the small enemies which beset his forward progress. He has done one great thing to stay their overwhelming advances—made use of natural checks by setting one form of life against another. In this way he has made vast strides in the reduction of mortality due to contagious diseases. In like manner he has made use of the so-called method of biological control in the subjugation of serious insect pests and as a beginning has already made notable progress in the reduction of certain ones like the cottony cushion scale in California, the sugar-cane leafhopper and other sugar-cane pests in Hawaii, and the woolly apple aphis in many parts of the world. Similar experiments with other insects are now being vigorously pursued in many parts of the world. Unfortunately in this connection he has exterminated or so greatly eliminated many insectivorous birds and mammals as actually to have favored and protected the insects.[1] Listen to any bird man and you wonder how we are able to carry on at all because of the destruction of the feathered tribes!

The question of man's influence upon insects should not be concluded without some word regarding those which he has been able to utilize for economic gain. The most remarkable of these, the silkworm, has become truly domesticated and would probably disappear completely if man's care were entirely withdrawn. The honeybee, though extensively raised for hundreds of years, shows its lack of dependence upon the human race by turning wild wherever it has been successfully introduced. Chinese wax, pela, is definitely reared and tended by the Chinese under conditions which it could not survive without human aid. Cochineal was given a wide distribution as a commercial product and is now being employed in an attempted eradication of introduced cacti in northeastern Australia. The lac insect is utilized as a natural product in India and its preservation from natural enemies is in direct contradiction to the method of biological control. Larger insects have long been utilized for food and I see no reason why, if man is ever hard pressed by these enemies, he can not turn to them as a source of subsistence!

This has been an extremely loose discussion of a most important and difficult problem which faces, not so much our immediate descendants, as it does those in more remote ages. Though we have laid some foundations looking towards the protection of future generations, we have not fulfilled our responsibilities until we have aroused mankind to the full appreciation of the true situation. A world consciousness must somehow be evolved. After this is accomplished in the so-called more enlightened nations it must be instilled into the minds and lives of the most backward and unrefined, for no part of the world is safe so long as

[1] E. H. Strickland. "Can Birds Hold Injurious Insects in Check?" SCIENTIFIC MONTHLY, 26: 48–56 (1928).

these insidious foes are allowed to exist in the remotest corners of the earth! This is a task too enormous to be accomplished by entomologists alone. Much of our time and energy is consumed by the many urgent local problems that require immediate attention. However, it is first and foremost our problem. We should recognize its seriousness, its difficulties and its possibilities for solution. We have made a beginning in the use of quarantine methods for preventing the distribution of insects; the use of toxins and poisons for their immediate destruction; and the method of biological control for their more permanent subjugation. We yet need to reform radically our ideas of home and city sanitation, including personal hygiene and the cleansing or destruction of domestic house animals; better methods in agricultural practices such as more intelligent crop rotation, breeding of resistant crops, crop elimination, planting and harvesting; better methods for storing cured and dried food supplies; and foremost a realization of the importance of a thorough scientific knowledge of all phases of insect life and the intricate part played by insects in all aspects of human welfare!

Ours is not the menial chore so often alluded to as "chasing bugs," but rather the gigantic task of saving the human race!

PREHISTORIC FEMALE FIGURINES FROM AMERICA AND THE OLD WORLD

By Dr. E. B. RENAUD

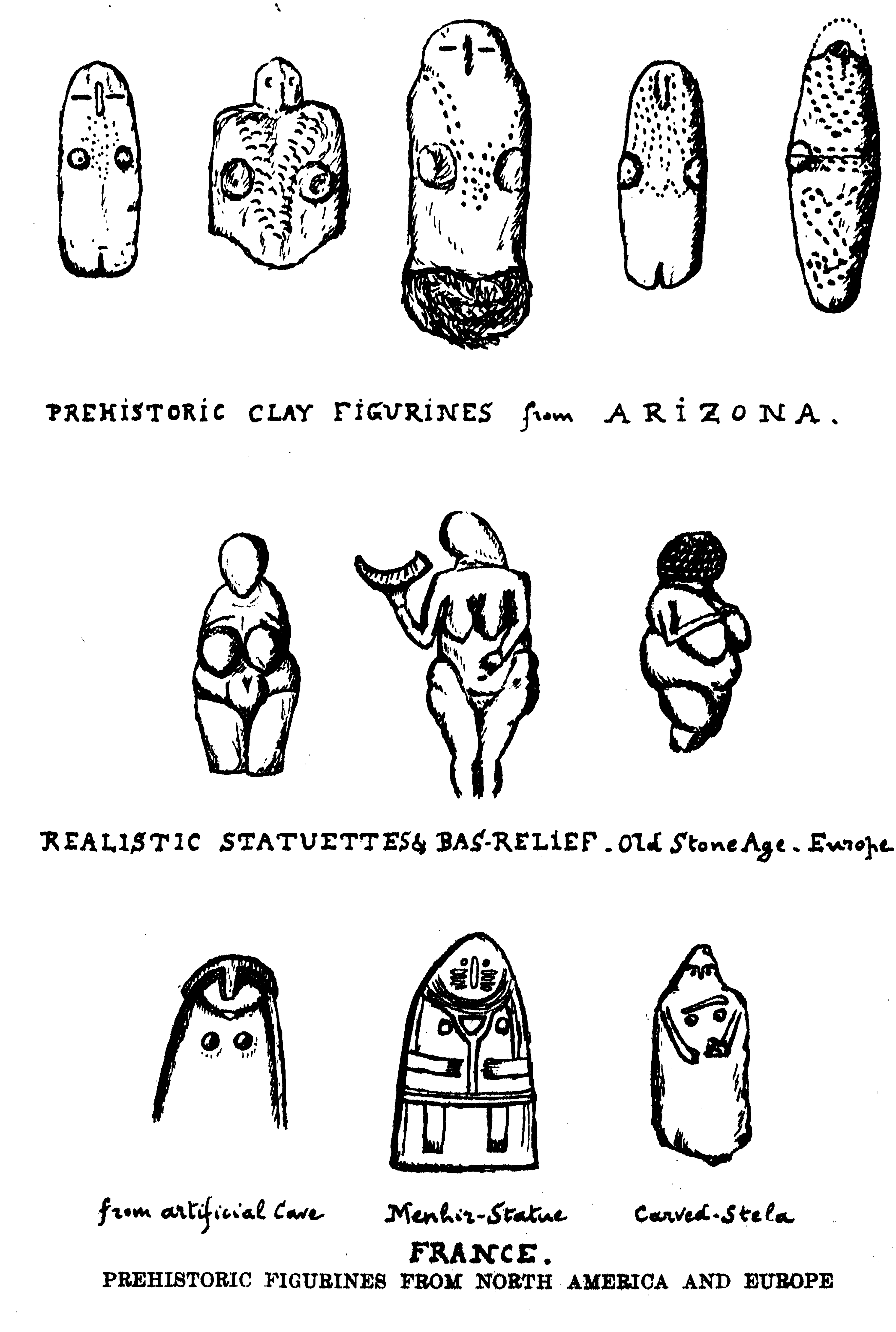
DEPARTMENT OF ANTHROPOLOGY, UNIVERSITY OF DENVER

THE first god was a goddess! This bold paradox seems justified, at least, in the light of archeological finds made both in the Old World and in the American southwest. And we have nothing to the contrary that could militate against the concrete evidence afforded by female statuettes discovered by anthropologists in various parts of the world.

The contributions to the cause of feminism among our ancient deities on this continent come from northeastern Arizona. They are due to two distinguished scientists, friends of mine. The first and larger group of these figurines was dug up in the Cañon del Muerto district in 1924 by Earl H. Morris, now of the Carnegie Institution. On account of the conditions and objects associated with them the explorer ascribed them to an early place in the Post-Basket-Maker Culture, say about 500 B.C., if we accept Dr. A. V. Kidder's suggestion. Two specimens of these little fetishes had found shelter in a corner of the Museum of the University of Colorado, where, with astonishment and interest, I discovered them in 1925 and soon made them known by means of an article in a French review. The rest of the lot attained metropolitan prominence, being housed in the American Museum of Natural History of New York, and were later presented to the scientific public by Earl H. Morris himself in his excellent monograph, "The Beginning of Pottery in the San Juan Area." They are roughly made of a brownish clay and shaped in the form of a small slab, blackened in places as if by frequent handling. They vary in dimensions from fifty-nine to a hundred and twenty-two millimeters in height, and twenty-seven to forty-six millimeters in width and some twelve to eighteen millimeters in thickness. Their main characteristics are essentially the same for all seven, three of which are complete, the others fragmentary. Nose and breasts are usually in high relief, eyes horizontal when visible, a median cleft at the crotch indicating the female organ. In four instances, two of which are very clear, the punctations made in the clay when moist suggest a necklace. The lower part of one figurine is covered with an apron similar to that scanty garment so often found on female skeletons in burials. None have arms or legs.

I also described two other similar statuettes now on display at the Museum of the University of Arizona, at Tucson. They were both found by Dean Byron Cummings. One, reddish in color, comes from Monument Valley, northern Arizona, and conforms to the previous type, but its primitive ornamentation is more extensive. The second is made of whitish clay and was found in Sagi Cañon not very far from the other. It is finer both in decoration and shape. Square punctations draw a triple necklace, then three horizontal lines between the breasts are seen, and the lower portion of the figure seems wrapped in a garment adorned with an oblique Z-shaped design. This better made and more artistic figurine may belong to a somewhat later development than the crude representations from Cañon del Muerto, or may simply be a local variation.

These prehistoric female statuettes, the only ones published so far, are the earli-



PREHISTORIC FIGURINES FROM NORTH AMERICA AND EUROPE

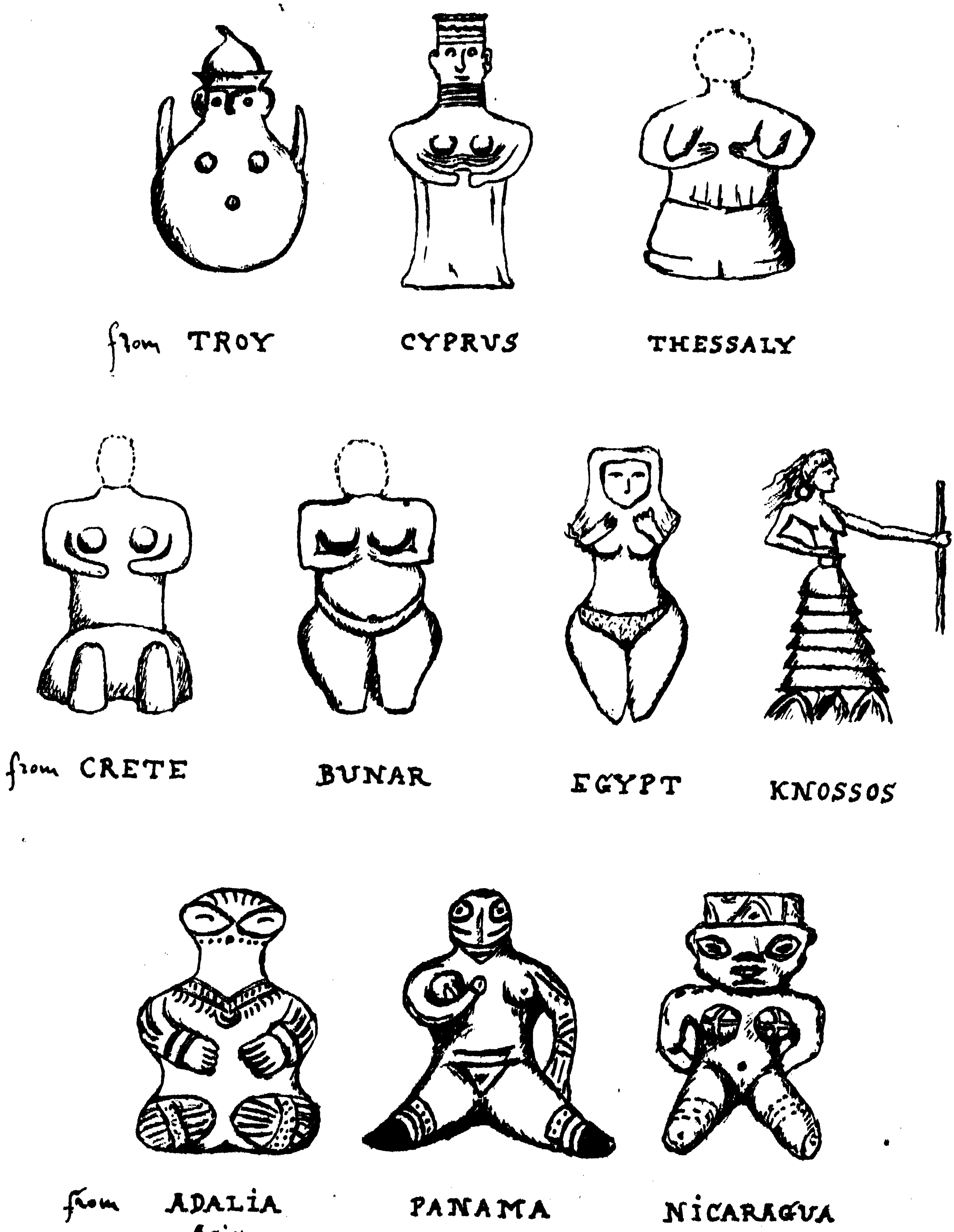
est human representations known from the American southwest. They are typical of the Post-Basket-Maker period, as none have been reported from Pueblo ruins. They are quite valuable for being so rare and ancient and also very interesting. Can we venture an interpretation? Although rough in presentation they are evidently human and just as clearly feminine and they show traces of frequent use. In view of the psychology of the primitive people who fashioned them, and of others known elsewhere, we may reasonably suppose that we have here fetishes of the feminine principle of fecundity and reproduction as suggested by the prominent breasts and the notch at the base of the figurine. They would represent some sort of a goddess of life, regardless of the belief and ritual possibly connected with them. Found in burials, they may have been placed near the dead as if to give them some kind of post-mortem life. This is not mere speculation and it acquires even a certain degree of probability in the light of our knowledge of Old World archeology, for in Europe, too, the first god was a goddess!

Thus, the most ancient statuettes known date from about the beginning of the Upper Paleolithic period, and are attributed to the Aurignacian people, negroid and possibly Cro-Magnon. They are carved out of stone, bone or ivory, some rudely shaped, others more artistically. The female characters are very much in evidence and even in some cases exaggerated. Leaving out their possible racial features, what seems striking is the fact that they are not representing any particular woman, the face being generally indistinct, but merely womanhood, fertility, reproduction of life. This is a point of resemblance with our rude Indian figurines. Moreover, their being often found in graves suggests their probable association with some belief in post-mortem life.

Leaving the fine realism of the upper stage of the Old Stone Age, we pass a barren aniconic phase and find in later Neolithic times only barbaric representations, sometimes hardly human in form as they are strongly conventionalized. They are scattered over several provinces of prehistoric France. In the Marne district they are carved on the chalky walls of the artificial caves used as burial chambers. The nose is in high relief as well as the eyebrows, while the eyes are sometimes indicated in black; we see a necklace with a single or multiple rows, and often the breasts are clearly visible. We recognize here several characteristics of our Arizona figurines. The Neolithic figures from Champagne have been interpreted as feminine idols, primitive personifications of maternity and akin to the type of the goddess-mother so popular in all the ancient world, according to Déchelette. Their close association here with sepultures shows them in another of their functions, as tutelary divinities of the dead.

On dolmens near Paris rudimentary forms of the same nature have also been recognized but here are even reduced to what seems their essential elements, the breasts and necklace. Evidently this marks the passage from the idol to the symbol, a natural stage of evolution.

In the southern part of France we find carved stelae and the so-called menhir-statues. The general outline is there closer to our American figurines. When the head is still present one sees eyes and nose but no mouth, the breasts sometimes in relief and the clear tracing of a necklace. The rest varies with different specimens. In one section of this area of bas-reliefs, as so far mentioned, there are true statues carved on all sides of a block of stone. A series of the latter group always represents a feminine idol with breasts and necklace; then, in its most characteristic elements, similar to the specimen from the north. We have, therefore, in that period, widely scattered over Neolithic



PREHISTORIC FIGURINES FROM GREECE, ASIA AND CENTRAL AMERICA

France, a more or less realistic or schematic representation of a female deity, a goddess of fecundity and life, associated with the dead. In her essential features and in her probable meaning there is a strong parallelism with our Post-Basket-Maker fetishes.

But these idols in their double aspect of goddess of life and funerary divinity, found in Western Europe in Neolithic and early Bronze times, are members of an extensive family found from Asia Minor to the British Isles. They seem to come from a common Aegean prototype. In the function of tutelary deity of the dead we find her ancestry in a double line of representations belonging to the pre-Mycenaean epoch, one on vases and the other on slabs of marble and schist. Thus, on ceramic specimens from the second city of Hissarlik, or Troy II, we see a symbolic figure with nose and eyebrows, sometimes eyes, never any mouth, but the breasts represented. This type spread from Asia to the Greek archipelago, the Iberian peninsula and Gaul, finally reaching Great Britain, carried by sailors and traders, as commerce was already active along land and sea routes. In these countries stone idols show the same characteristic features and all date from the end of the Neolithic and the beginning of the Bronze Age.

In opposition to the functions of that female divinity in regard to the dead, we may consider now her more cheerful aspect, her personification of fecundity and abundance of love and life. The Orient and a few European countries have honored and worshiped a goddess-mother, symbol of fertility for everything alive—men, animals and plants. Thus we must not be surprised to find her representation multiple and diverse, here rude, there artistic, now realistic and at other times reduced to a few essential characteristics, and even becoming a mere symbol, in places, carved in stone, in others modeled in clay, and even pictured on gold rings. The Chaldeans called her Nana, the Semites Astarte, the Phoenicians Ashtoreth, the Greeks Aphrodite, and the semi-barbarians of the West gave her names which have not reached us.

In the lower strata of Susian and Chaldean ruins were found very crude images of our goddess and later figurines with a wealth of details of body and head-dress, for Nana was nude except for the traditional necklace. In Egypt we have both the realistic statuette and the symbolic, bottle-like outline, in either case with sexual characteristics outstanding as in Mesopotamia. The same can be said for the interesting statuettes from the Trojan district, naked but with necklaces and elaborate head-dresses. In the Greek islands and especially at Cyprus, besides naturalistic representations there is a tendency towards a stiff conventionalization. Not all the figures are standing, some are merely busts with breasts visible and multiple necklaces, others are squatting, as also seen in Cilicia. They lose then much of their artistic appearance. In Crete we have also seated and crouching figurines, made of clay and a variety of stones. Some of the more realistic are adipose and steatopygous like the Aurignacian statuettes and bas-reliefs of southern France. A strong tendency towards a simplified, purely symbolic and at times almost amorphous type is witnessed in many places in the Greek Cyclades, Crete, Asia Minor and the hinterland as far back as the Euphrates and Caucasus. On the European continent, on the contrary, we find many more or less realistic images of the same goddess in erect position such as in Thessaly, along the Danube valley, in Transylvania and southern Russia, generally in the nude, sometimes, as in Cucuteni, the body is covered with parallel curvilinear designs, painting, or tattooing, in other places richly dressed and adorned as at Kličevac, near Belgrade. But in the center of the area, in the Aegaean civilizations, whether in

statuettes of stone or clay or on gold rings, from Mycenae, Knossos or elsewhere, even when the goddess is otherwise dressed, the breasts always remain visible and prominent as the very symbol of the Goddess-Mother. The interesting representations of the Great Goddess on the gold rings of Mycenae, Isopata, a seal from Knossos and other instances, show her with a skirt, but the bust bare, thus recalling the figurine found by Morris in the Muerto Cañon, still with the apron as worn by the women of the time, but the upper part of the body naked.

Thus, under a variety of forms according to countries and times but with the essential characteristics of an attractive female body, we see in the regions bordering on the Mediterranean Sea and even far inland, many statuettes of the goddess of fecundity and life. Humble as they are, our little prehistoric Indian figurines belong to the same divine family and betray the same psychology in primitive men of different continents. What is common to them all is the idea, personification and worship of the life-giving mother, and her essential characteristic is, besides secondary attributes and variety of representations, her nourishing breasts. This is the thought emerging from our rapid comparison. Primitive men from Asia, Europe, Egypt, as well as America have honored and prayed to a benevolent female deity. The first effort of the early Indians of the southwest was the crude modeling of their goddess of fecundity and life, also, maybe, a tutelary divinity of the dead, thus following unknowingly more civilized peoples of the Old World.

But one more point remains to be considered. Some of the less artistic and realistic squatting statuettes from Cyprus and especially Adalia, in Cilicia, Asia Minor, recall to mind some of the archaic American figurines from Central America, such as Spinden has described for Nicaragua, Panama and neighboring countries. One sees in them the same tendency to a broad, flat head, large oval eyes, decorated body in a sitting position. These female images, although the ones were made in western Asia and the others in America, may have had the same general meaning, a product of a common human psychology, and have led to beliefs and practices not so different after all. These archaic figurines probably originated somewhere in Central America, cradle of the Indian civilization, where agriculture started first and pottery later on. From there they spread to South America, following the coasts as far as the Isle of Marajo, Brazil, on the Atlantic side, and Peru on the Pacific, while north they gained Mexico. Now, if one considers that Arizona is located in the marginal zone, far away to the north, having developed agriculture after receiving maize very likely from Mexico somewhere about 1500 to 2000 B. C., having started pottery in the neighborhood of 500 B. C., according to Kidder's suggestions, can we not think that our little female figurines are like the last born of an extensive and varied family or as an echo of the archaic art of Middle America? Even if they are not directly connected with the Central and older American group, more advanced and artistic, it seems fairly probable that they represent much of the same impulse, that they embody a similar belief and personify the same goddess-mother, divinity of reproduction and general fecundity, fertility and abundance, love and life, and may be also a protector spirit of the dead—what we have seen true for the Old World was possibly also the case in archaic America. But, as this feminine cult disappeared in Egypt with the Pharaonic civilization, so it seems to have vanished too from the southwest, at least as revealed to us in the form of Post-Basket-Maker figurines, with the coming of the Pueblo Indians in Arizona.

THE DEVELOPMENT OF CULTURE IN RELATION TO POPULATION

By Dr. WALTER HOUGH
U. S. NATIONAL MUSEUM

How do man's reactions to his near needs differ from what are called instinctive habits, as observed in a bird selecting material and building a nest? Where is the point at which instinct is separated from reactions that are plus instinct? There has come to man gradually and unconsciously something different, higher and capable of important expansion. It is easily believed that man's culture and his physical development went hand in hand. This may be pursued from the postulate stated. It may be conceived that man's advance was promoted by interactions between his consciousness and his inventions, the latter leading to changes in habit which reacted upon his physical make-up. Manifestly nothing definite appears in the earliest periods, in which there must have been transitions, upon which to base even imagination as to physical changes leading to man. When something tangible is reached it appears to burst upon us as a rude culture whose imperishable part consists of an extraordinary amount of a recognizable stone artifact scattered in the drift which has dispersed the evidences of early sites, also the evidence of other culture objects besides stone. We need the Eolithic stage for landmarks of the early period which presents, as stated, embarrassing difficulties of detection. We do not feel sure that the Eolithic has been detected yet, but for that matter who can say where are the evidences that beginning man passed this or that way? Who could find definite fixed traces of the movement of a band of apes in the forest?

Development implies a beginning, or rather merging from one state to another with at first almost imperceptible changes.

The scientifically directed imagination pictures a stone clumsily taken in the hand and thrown aside when the temporary use is over. Again, the stone is carried to a place where a simple need is indicated, thus becoming a known stone for a certain use or for various uses; it comes to show traces of human contact if not traces of use. If laid down and left, it may be selected and picked up again. The stone, having served adequately, may finally be kept for personal use, and be in effect the simple hammerstone so often observed in use among tribes of low culture or perpetuated among more advanced tribes. The hammer in due course may be pitted on the sides for holding, grooved for hafting, and so forth, always remaining a typical simple tool till the age of invention. In use the hammer may chip or spall, giving a cutting edge, and begin the ax series. Instead of the water-worn boulder, a splintered mass of convenient size with cutting edge may be taken up and the development proceed in the order as above.

It is conceived that the simplest and most fundamental tools which required force in their use were the first and most profound modifiers of man in a physical sense. These in use demanded unnatural attitudes, postures, pitting of

one muscle against another and repetitions not demanded from any animal in nature. The crude tools prepared man's hands and body for the use of other tools and implements requiring handling with more skill, hence the development of tools from rude stones into the variety of implements found by archeologists in the successive human layers of strata. It is suggested that the human vertebral curves are due to work with tools. In this way the contour of the spinal column observed in man may have been differentiated from that of the great apes, which is simply curved, to the concavo-convex spinal curves of the human being, which furnish a fulcrum for work with the hands and arms, or generally with the whole musculature of the body. It follows also that the osseous structure would be modified.

The stimulation of invention and the development of material culture is seen to be involved in the increase of population. This may be formulated as follows: With small population environment tends to remain natural; with increasing and large population environment tends to become artificial. That is, the interplay of forces which tend to the production of useful arts and inventions are greater in larger than in smaller aggregates of man. This idea is capable of elucidation and enlargement to any extent.

At the proper place and time and culture stage other inventions occur, as observed in the comparative table of arts in the various archeological stages shown in MacCurdy's "Human Origins." These steps admit of a description of the development of material culture because on the whole there has been progress from the beginning and retrogression takes a negligible position. The study of the development of the arts and industries is based upon and made comparatively easy by the facts of the stratigraphy mentioned. The profound thought here is that there has been progress, be it ever so little in the earlier stages.

The population of the earth has increased till it is greater at present than at any time in the world's history. Against disease, war and all other forms of life termination the population increases. In view of the present increase it may be of interest to speculate on the growth, ebb and flow of population during past periods.

Man belongs in the order of mammals. In his growth there has been developed the type of mammal enforcing the production normally of one offspring. This feature is considered as one of the evidences of the high and mature development of man. Coordinate with the slow birth-rate of man appears the feature of the care of the offspring, helpless through a continuing period. The effect of this on the development of future population can be seen. With this apparent handicap it is evident that the species of man as a natural animal would have made very slow progress in populating the earth. This is exemplified in the far-descended lines of the great apes, which, so far as is known, never have shown the character of fecundity leading to great numbers of individuals that is observed in other groups of mammals. The apes, it may be conceived, were animals set apart by bodily characters and habits not necessarily to become man, but in whose stem the man being could and would develop. The physical preface to man, it is thought, would not require adjustment within large groups as is conceived necessary for the populational impetus to man's culture advance. Man-like beings in the stage of beginners as described were not intruders because they were beings developing along natural so-called laws of environment, and so forth. They were static or delimited. However, these man-like beings, or some

of them, had within them the germs of certain capabilities based on physical form, members and attitude. Tool using and language capabilities may be referred to. The development of these extra facilities must eventually class these beings, having become man, as intruders in the slow-moving scenes of nature. So it may be put forth that, without the acquisition of several arts or sequences of artificialities governed by mind of a higher quality than previously developed, the consideration of population would be useless.

In the earlier stages represented by the artifacts of some of the man stem it is conjectured that the population was nearly stationary. That the man stock persisted through geological changes in his environment and that through very long periods of time he was subject to unknown causes of mutability is beyond question. That his arts also persisted, slowly developing at first and gradually at a more rapid rate, is evident in the sequence of layers containing the indestructible artifacts from his intelligent labors. Man is seen as becoming man through his arts. The lines of this development showing always advancement in the basic arts are clear. The genealogy of the workers still shows many gaps, hoped to be filled in the future. In view of the number of earnest students and the wide-spread knowledge of the conditions of the problem, the lacunae of skeletal remains may be filled sooner than anticipated.

In considering population the time element is important. The strata containing artifacts, found at various horizons, mean either the accumulations of many workers in a short time or the product of few workers over a long period, presumably the latter. The time scale of the classified periods given by archeologists, though tentative as to duration of the periods, appears to answer this question in the negative regarding numerous population at any time before the Neolithic.

The discussion on these facts would consider the culture stage, the animal and vegetal environments as affecting the increase of population. It is a fact that meat-eating hunting tribes have a slow rate of increase. The first important stabilization of man admitting of increase of population was pecudiculture. The second, which is greater and on which our population increase is based, is agriculture, beginning with the gathering of natural crops of food plants. Observations on tribes lowest in culture among present man would have a bearing here and bring out the fact that the Negritos, Veddahs, Australians and others which could be mentioned have a very limited increase. It is seen that climate, food, housing, care of infants, etc., are involved in this inquiry.

In view of the foregoing speculations which only attempt tentative conclusions to the contents of our present knowledge of the growth of man mentally, that is, in his arts and as an inhabitant of the earth, we can not assume any numerous population before the Neolithic. The Neolithic, it must be observed, is a very short step back in man's history.

When we come to consideration of Neolithic man we are freed to a large degree from the necessity of speculation. Men with Neolithic culture have survived into historic times and from them much may be gathered to show that the stone art which gives the period a name was in reality subsidiary to wood, textile and other material phases of the culture. Considering the Neolithic from the European stations, which are classic to the archeologists, there is seen not what geologists term non-conformity, but a zone of transition between the Neolithic and the preceding culture. There evidently appeared something which profoundly differentiated the

Neolithic, and this may be called the elaboration of the arts and industries. As a further characterization the Neolithic is the dawn of the industrial age and it is at once marked by a mediocrity of art feeling and the multiplication of forms. There is shown the increase of population far beyond the sparse peopling of earlier times. This argues for an organization of the means of sustenance, a development of agriculture, transportation and commerce. The needs of the many are the fertile ground of invention.

Taking up the arts we find the beginning of ceramics with all that implies as to household life, and an early use of fire in industry. The ceramic industry is one of the outstanding features of Neolithic culture. The art of pottery making would seem to contribute importantly to the succeeding age of metals as suggested in another paper.[1] As with the Neolithic culture the same may be said of Paleolithic culture and possibly as to Eolithic. The remarkable point is that each of these groups has individuals with possibilities of culture advance equal to that of the civilized groups. They also appear to show types of intellect, disposition and the like and of physical make-up similar to modern men who have long been subjected to the mass of inventions of the age.

It is evident that a culture pattern underlies our human make-up, the same with all races, nationalities and linguistic stocks. Upon this is based the thesis that it is numbers that make for the advance of culture provided other conditions are equal.

An estimate of the population of the world during the index periods may be tentatively put forward here. The Chellean may be put at 5,000, growing slowly through the Old Stone periods to the Neolithic, which may have had 1,000,000. The Bronze Age would be assigned 1,500,000; the archeologic Iron Age, 20,000,000, while the present has about 1,600,000,000. Thus the wide sweep of important advances of the human race is accompanied by great increase in population. The interesting subject of population growth has been lucidly treated by Dr. Raymond Pearl. Dr. Pearl concludes that the increase in numbers is slow at first, rises with increasing rapidity until a saturation point is reached, at which time stability is attained and no further increase takes place. As seen in ancient examples, currents within the mass producing local condensations and eras of well-being have the effect of promoting the culture of the whole body.

Again and again the observation is made that after the initial impetus given as suggested by increase of population needs, a general conservatism in arts supervenes, little affected by local or periodic adjustments. This is observed in Egypt throughout the long scale of art essentially permutations and combinations of the Thinite impress from dawn to extinction upon which no innovations could make an impress. Thus the schools recognized by Professor Maspero—Thinite, Memphite, the Theban, the Hermopolitan, Tanite and the secondary schools of the Said and the Delta—appear to be responses to population pressure in a broad sense.

Clearly while the facts seem to show that under the stimuli of increased numbers culture takes on a new advance, the effect of the presumed law in dense populations is often annulled by unfavorable conditions such as overpopulation and the consequent struggle for subsistence. Thus Dr. H. J. Spinden has shown that Java has a density of population of 730 to the square mile. This increase has mounted in recent years, but with it no results of invention or other culture phenomena have been

[1] "Man and Metals," *Proc. Nat. Acad. Sci.*, Vol. 2, March, 1916.

observed as yet, due no doubt to the limited operation of the time element. The characteristic culture of this island took form many centuries ago, presumably through acculturation from India modifying the native base.

As to the quantitative and qualitative ratios between population and culture no data can be furnished. It is not clear that such data for ancient times are within the possibilities at present. It can be shown, however, that important inventions or even whole series of consequent procedures originate at favorable phases of human progress. Basically culture is a response to needs which can be supplied only from the conditions of human environment at the time.

A great discovery is due when we are able to correlate the effect of material culture and surroundings with the development of man physically, mentally and morally. What we will discover is the force exerted by material culture, its expansive and propulsive dynamics.

Incidentally, the belief in man's superiority in nature was inevitable, and the idea unfortunately complicated world beliefs tremendously. Man's progress from a rude state prefigured in the Edenic account lost sight of, he stood out at say 1500 B. C. as a unique phenomenon in nature, to account for which a special creation was required. There was, in brief, no other explanation adequate in the consciousness of the supremacy of man.

Whatever man's future, his origin and development into man through all the lower stages were on a definite line—shall we say predestined from the first? There was no course of evolution by which a race of horses or grasshoppers should inherit the earth and attain to organized society of civilization. All things worked out for the development of the hand that should discriminately grasp tools and lay together fire on the hearth, the tongue which should be free to form speech and the mind that should correlate activities and ideas. In all these interacting forces we may recognize a plan so comprehensive and majestic as to form the pattern that underlies human history.

There is seen the line of coming man, never obliterated through all vicissitudes. There is seen man disengaging himself from the heavy trammels of unconscious nature and by each advance helping himself to more permanent continuance. The conception of the ascent from cell to man, jealously guarded through enormous time, is an ennobling thought harmonious with the logic of creation.

HOW SHALL WE MEASURE THE QUANTITY OF LIFE OF AN ORGANISM?

By Professor ALBERT P. MATHEWS
DEPARTMENT OF BIOCHEMISTRY, UNIVERSITY OF CINCINNATI

MATTER in the non-living state possesses electrical, magnetic, mechanical and geometrical properties. All these different properties can be measured and the quantity of matter expressed in terms of any of them. No method exists, however, for determining and expressing the quantity of vitality that same matter shows when organized into a living being, nor can the quantity of matter in such an organism be expressed in terms of units of vitality. Yet vitality is a material phenomenon and is just as much a quality of matter as is any one of the physical properties mentioned.

Since the discovery of a means of measurement of any particular quality of matter has always been a necessary step in the discovery of the nature and laws of the quality itself, and a science becomes exact, rather than descriptive, only when such a method has been discovered, biology, since it lacks any method for measuring the quantity of life, remains in the descriptive and qualitative stage. It can not escape from that stage and become an exact science in which certainty takes the place of conjecture until such a method has been found.

While several of the physical phenomena of life can be measured, as, for example, the rate of respiration, the basal metabolism or the electrical current which accompanies all forms of vital activity, yet since none of these phenomena is exclusively confined to matter in the living state, we are at a loss to express the quantity of life in terms of any one of them. But the principal objection to all these methods, even though they might be standardized in terms of units of vitality, is that what is measured by them is not the organized vitality of the organism. So much of the human body is outside of the nervous system, which is the part concerned with individuality, that marked disease or depression of this system may be present and yet there be little or no change in the total metabolism of the body. A man's muscles and glands may be of normal vitality, and yet his nervous system be so far from normal that his real vitality as a man may be extremely low.

To devise some method of measuring the amount of vitality it is necessary to get a clear idea at the outset of just what it is we should try to measure. What is vitality? What, if any, are the particular and exclusive, objective evidences of the existence of the integrated vitality of an organism—of its individuality — which we might measure? Neither chemical nor physical phenomena are known which are exclusively confined to living matter.

There are two, and I believe only two, characteristics of life which are not shown by any non-living thing. There are two characteristics which matter exhibits when organized into the state called living, and which it does not show, although it probably possesses them, when it is not so organized. These two characteristics are consciousness and will; consciousness and power of action. Not only are these the fundamental and characteristic things in the lives of every one of us, but it is certain, or so it seems to me, that they are equally fundamental for all forms of living matter. All

living things, without exception, show something of the same power of action of an internal source which we show; and they all show power of choice and of learning, a behavior which clearly indicates that they have some form or quantity of consciousness. Consciousness is, indeed, simply another name for being. To be, to exist as an individual, is to be conscious; to have some awareness and power of thought as an individual. And to have will, is to have an internal power of action.

Living things differ in their behavior from lifeless things because they possess these two characteristics as living units or wholes. The individual is conscious and has will and acts as a whole. The amount of its life as an individual and as a whole—not its life as the summation of the lives of separate tissues and cells—is shown by the amount of consciousness and will it possesses as a whole or unit. There can be no doubt, also, that these phenomena of unitary consciousness and will depend on some sort of organization which is peculiar to living things, for any disorganization of a living thing is invariably accompanied by the disappearance of these qualities; and when they disappear the organism is dead although the life of its individual cells may persist. A tree is a less well organized living unit than a man, and it undoubtedly has weaker powers of consciousness as a tree, and a weaker will, than man has as a man. Its powers of action as a tree are small compared with those of a man, and its consciousness as a tree is probably very feeble. Its individual cells, however, are presumably just as efficient as are those of a man; they may be just as conscious and have just as good a power of choice and of action as the individual cells of a man; so far at least as one can judge. The difference between tree and man is a different degree of synthesis or integration into a large living unit which has consciousness and power of action as a unit, as a whole, and is not simply an assemblage of parts. In this respect man is vastly superior.

We come then to the conclusion that matter when organized into what we call the living state shows the two phenomena peculiar to living things of consciousness and will, and these pertain to the organism as a whole. These, then, are the truly vital characteristics. They are not shown by any dead organism, although they may, and I think probably do, lie concealed in such dead organisms. Our problem is to find a method by which consciousness and will can be measured physically and expressed in physical units.

To measure the quantity of vitality of an organism, as an organism, we must, then, find a method of measuring the quantity of its consciousness and will which it possesses as an organism, rather than the sum of the individual consciousness and will of its cells. What I want to know about my own vitality is not how much vitality I have in my muscle cells and the other cells of other tissues, but how much vitality is synthesized or integrated to make me; to make my personality. Every one instinctively feels that his body is not he. For it is upon this integrated portion of vitality, and not upon my basal metabolism, that the intensity of my consciousness, power of thought and of action, and strength of will depend. If I am etherized, for example, or rendered unconscious by a blow on the head, my consciousness and power of will are altogether lost. My integration (organization) is temporarily done away with. I temporarily die. But the basal metabolism of my muscles, bones and glands is very little altered. So, also, I may be in a katatonic state, such as that of dementia praecox, with almost no automatism, with little power of will and very little consciousness, and yet if my vitality be measured by my basal metabolism or by the amount of my respiration or by the electrical reactions of

my tissues, it will be found to be almost normal. Evidently these methods, while they may be a partial measure at least of the vitality of my tissues, do not measure that vitality which is I; and it is this latter which constitutes the vitality of the organism as an organism, as a whole or unit. The better the organism—the more perfect its living organization—the stronger will be its personality, the stronger its will, and the more intense its consciousness and power of thought. Such an organism, for example, as Leonardo da Vinci is one of the most perfect which has been produced. We want a measuring scale which will enable us to measure accurately the amount of this vitality in a Leonardo da Vinci—his vitality as Leonardo, rather than the vitality of his separate muscles, bones and glands. Any good pugilist would probably show just as good a vitality in the latter sense as would Leonardo, perhaps a better; whereas the real life of Leonardo, as Leonardo, is vastly superior to that of the pugilist.

I can make clearer what it is necessary for us to measure by considering another kind of organism, a dead organism, a magnet. A magnet is an organism of such a kind that the magnetisms of the individual particles composing the magnet are organized into a whole. This organization brings its concealed property of magnetism into the clear light of day, for it makes a large magnetic unit for us to see and study, in place of the very little, individual magnets of the particles of which it is composed. The axes of these magnetic particles are so organized by being similarly directed that the individual fields of the particles no longer mutually extinguish each other, but fuse to make a large magnetic field. If a piece of soft iron showing no external magnetism be acted upon properly, that piece of soft iron will be converted into a magnetic organism, a personality or individual. Now the magnet so formed may be a good or poor personality. Its magnetism may be strong or weak, depending on the excellence of the orientation—that is, the excellence of the magnetic organization—of the particles of which it is composed. What we want to know about the magnet is not how much total magnetism there is in it, the sum of the magnetisms of its particles, but how much of that magnetism is organized, synthesized or integrated into an individual. The total amount of magnetic flux in the iron of which the magnet is composed is probably unchanged whatever is done to the iron. But the more perfectly it is organized, the better is the magnet as a magnet. If the magnet be heated, its personality is lost. All its external magnetism, its personality, disappears; it becomes simply a lump of iron; but the total amount of magnetism in it is still there and unchanged. All that has happened is that heat has destroyed the organization. When the power of a magnet is measured, what is measured is the quantity of its magnetic personality, not the total quantity of magnetic flux in the magnet.

It is just so, I believe, with the phenomena of consciousness and will. These phenomena are probably in all matter; but only when the particles of that matter are oriented in a certain way is there produced out of that matter conscious, willing individuals. If a man be anesthetized or killed, or even if he sleep, the total amount of consciousness and will in his body is probably not altered; all that has happened is that the organization has been temporarily or permanently changed, so that the mental fields of some of his molecules are variously directed and he is partially disorganized and resolved into a chaos of atoms, molecules and cells.

The real vitality of any organism, its individuality in other words, can only be measured, I believe, if there be about that organism what may be called a vital or mental field. If such a field exist and we can find a means of measuring it, then

we will have a means of measuring organisms as organisms, and of comparing one organism quantitatively with another. When we discover this method then we may discover whether or not there has been a real progress upward of evolution, for we shall be able to compare the mentality of a bacterium, or any other organism, with that of a man, and classify all living beings in a real classification based upon the quantity of their organized vitality per gram of matter.

Is there any reason for thinking that such a field exists?

Such a field must exist, if the hypothesis as to the nature of matter developed by the author be true.[1]

In the book just cited I have developed the conception that matter is four dimensional. It extends in space and endures in time. So much, indeed, is a truism. These four dimensions look qualitatively different to us, whether they be qualitatively different or not. There are, hence, four aspects of all matter, corresponding, each of them, to one of the four axes of space-time. These four aspects are the mechanical, the electrical, the magnetic and the mental. Every electron, whether positive or negative, has these four aspects or qualities. Consequently in every event in nature there are mechanical, magnetic, electrical and mental components. These four events are in the four planes of four-dimensional space, for the electrons are conceived to be four-dimensional vortices which are either strained about all four axes, on the geometrical or formal representation of the cosmos, or have four components of motion, one about each of the four axes, on the mechanical representation. Each electron is surrounded by a field of stress and strain which extends indefinitely outward from it, which may be called an epi-electron, and which we recognize as the electrical field of the electron. In this field there are the same four components, and of the same amount, but oppositely directed, which are in the electron. Thus in the field there is virtual electric charge, magnetic flux, mechanical strain and mental strain, corresponding each to a real similar factor in the electron itself.

Corresponding to these four aspects of matter there are four kinds of organisms: the magnet, the electet, the crystal and the living organisms, or *mentets,* as I suggest they be called. In the first kind of organism, the magnet, the particles of which it is composed have their magnetic axes arranged in parallel; in the second kind of organism, the electet, the particles have their electrical axes arranged in parallel; in the third kind, the crystal, the organization is by the mechanical axes of the molecules or particles. In these mechanical organisms the hidden shapes and mechanical properties of molecules are made manifest to us; in the fourth kind, living organisms or mentets, the organization is by the mental axes of its particles. In them the property of mentality present in all matter is revealed to us. The fundamental material organization in living matter is mental.

Since every electron has the same amount of each of these four elements or qualities, and since by vitality we really mean consciousness and will, to determine the total quantity of vitality in any organism all that is necessary is to weigh it. The fat man has much more by this measure than the lean. But the scales do not show the amount of vitality which is the man himself; nor do they show the amount of his vitality considered as the sum of the vitalities of his different cells as vital units. They measure only the total vitality of all his electrons, since this is proportional to their weight or number.

How then shall we measure the integrated vitality of a man?

[1] "The Nature of Matter, Gravitation and Light." Wm. Wood and Co., New York. 1927. 218 pp.

The field about a magnet is essentially a magnetic field; that about an electet is essentially an electrical field; the field about a crystal, or about a material body strained mechanically, is a mechanical or elastic field; just so, I believe, the field about a living organism, or mentet, must be a mental field. The only way of measuring the strength of any of these organisms, as organisms, is to measure the strength of the corresponding surrounding field. How are we to do this in the case of living organisms?

There are two ways, I believe, which we should seek to follow and which may lead to the goal.

We are essentially mental organisms. So much is I think indisputable. A very, very small part of our matter, probably only a portion of the nervous system, and possibly a very small part of that, is so organized that it is a mental unit, and so connected with the rest of the body through nervous connections that, weak though it be, it can act upon the body by its mental force so as to release the body's energies and produce mass motions. In order to do this the possibility exists that all that is necessary is to change momentarily the orientation of some of the mentally polarized molecules of the nerve cells, and that this pulls the trigger, as it were, for the release of amounts of energy which are needed. The mental force, though weak, is a material force and like any other force is able to act upon matter polarized in its own sense, in this case matter mentally polarized, and the extremely small mass of the molecules moved makes it possible for the weak force, which we call will, to act physically and efficiently. For if we are mentets, we are almost certainly weak mentets, since the amount of matter in the real mentet of each person is probably very small, though how small can not be said. The smallness of its amount does not mean that it is inefficient, for the lives of very minute organisms, organisms too small to be seen even in the microscope, show that even very small collections of molecules, when they are properly organized, may be very efficient mentets, with consciousness and will sufficient to meet and overcome the usual vicissitudes of life.

To solve the problem of how to measure the supposed mental, or vital, field of an organism, I believe we must be guided by the experience of physicists in measuring their organisms of an electrical and magnetic nature. It seems that each of the aspects of matter just mentioned acts only on other matter through that aspect of such matter which corresponds to its own. That is, if the electrical charge on any object is to be measured, it is necessary to bring near it matter which is electrically organized; to measure magnetic flux the matter having the flux must act on matter so organized as to be a magnet. And we measure fields of matter strained mechanically by mechanical means. We do not detect magnetic flux by an electet; nor electric charge by a magnet. Nor can we expect to move any mass of matter by mental force unless that matter be so organized as to act as a mental individual. Otherwise the different particles composing the mass of matter, having their mental axes variously directed, will be moved in various directions, and there will be no movement of the mass as a whole. If then we are to detect such a supposed mental field about organisms, other highly sensitive mentets must be found which will react by molar motion of their matter when brought into the fields of such other mentets as we are. Since we are probably weak mentets, although possibly the strongest existing, we must either make very sensitive artificial mentets of small inertia, or we must find natural mentets, other living organisms for example, of intense mentality but small mass, so that they will react to a weak mental field.

It might be possible by observing such organisms to detect a change in their

motion or behavior when brought near a human or other living being, and in this way, by using these natural mentets, a method of detection and measurement of the mental field, that is of the vital field, of man and other organisms could be obtained. The strength of the field could thus be expressed in terms of so many ergs of mental energy per cubic centimeter, if the energy necessary to move the organism in question with a definite velocity were known. Thus the quantity of the real vitality of the organism, as an organism, could be expressed.

There is, however, another possibility which should be borne in mind, and here again we are guided by the history of magnetism. It may be possible to make artificial mentets which are not living in the sense that they are capable of growth and reproduction.

Originally, when knowledge of magnetism was young, the only magnets known were those found in nature, the lodestones. Then it was discovered that new magnets could be made by acting on iron by such preexisting magnets. But to make a magnet one had to have first another magnet; and it was a great question how the first magnet came to be made. At that time students of magnetism were confronted by the magnetogenetic law: every magnet from a preexisting magnet; just, as at present, we have the biogenetic law: every living organism, every mentet, from a preexisting living organism (mentet). Ultimately, however, it was found that a magnet might be made by acting on certain kinds of matter not by magnets but by an electric current. This was the artificial creation of magnets. Moreover, it is known that certain crystals, in which the organization is preeminently mechanical, have in addition a certain amount of electrical organization so that the different crystal axes have different electrical and also magnetic polarities. Now the possibility exists that in a similar way some kinds of matter, when organized either magnetically, electrically or mechanically, may also show some mental organization. Such matter would then be a mentet of an artificial kind, although it would probably lack the power of metabolism and machinery of action which characterize living mentets. Should such a chance discovery be made, it might be found that such a crystal, or electet, would be oriented if brought into the human or any other sufficiently strong vital field. And this might solve our problem. But this would be largely a chance discovery and I imagine a great many negative experiments will have to be tried before such a mentetometer is discovered, if indeed it be ever found.

In these two ways, then—first, by testing small living organisms (natural mentets) and looking for changes of behavior or orientation when brought near other organisms; and, second, by looking for artificial mentets produced mechanically, electrically or magnetically—it may ultimately be possible to demonstrate, and to determine the strength of, the mental field which, if the theory of matter I have published be true, exists about every living individual, and which alone expresses the strength of its personality and its vitality as an organism.

There is also another possible method of measuring this organic vitality which we may briefly consider.

If the objective aspects of consciousness and will could be identified, then we might measure the quantity of vitality in an organism, the strength of its field, not mentally, but in terms of such other objective things. Let us consider this possibility a moment.

What is the objective, mechanical aspect of consciousness? In other words what do we call consciousness when we see it in other objects than ourselves? For, of course, we do not recognize it in them as consciousness. Now it seems to

me that the objective, mechanical equivalent of consciousness is time. That which is in us consciousness, appears to us in others, when they are viewed as machines, as time. Time is a concept of mechanics. And its geometrical, as distinguished from its mechanical, aspect is one of the four extensions in space-time, that is in four-dimensional space. What the electrical and magnetic aspects of consciousness are need not be considered here, although their identification is not difficult. That consciousness is the subjective aspect of time and also of extension in space will be realized, I think, by considering the nature of time. We are subjectively conscious of the objective thing we call the flow of time. It is the succession of states of our consciousness. Time is being, just as is consciousness. Time may be defined, indeed, as that which is, has been or will be. There are three kinds of time, just as there are three states of being: past, present and future; or, I was, I am, I will be. Being is thought or consciousness. Hence time is the objective, mechanical aspect of consciousness or thought. That which in us is our flow of consciousness, we observe in others as a flow of time. Such others proceed from state to state of consciousness. They begin, and they grow old; most grow wiser as they accumulate consciousness or thought.

Time, geometrically expressed, is one of the coordinates of space-time; it is coordinate with extension in space. Hence the time axis of space-time is the mental axis of space-time.

Units of consciousness can then be expressed objectively in terms of mechanical units of time, or seconds; and in terms of geometrical units of time, as so many centimeters. Consciousness can also be expressed in electrical and magnetic units just as soon as the electrical and magnetic aspects of consciousness have been recognized. Its electrical aspect is possibly electrical capacity, since this has the dimensions of an extension in space. The older a man grows, the more seconds he has, the more consciousness he has had. His units of consciousness accumulate, and the quantity of vitality as an individual enduring in time is increased somewhat in proportion to his age. If the intensity of his consciousness at any instant becomes less as he grows older, yet the total sum of his consciousness is constantly increasing with his years. But here again we should have to measure and sum only those seconds, only that succession of states of being, which pertain to him as an organism.

So much then for the objective aspects of consciousness as time and as extension in space.

The objective mechanical aspect of will is undoubtedly force; and the objective mechanical aspect of emotion, or internal power of action, is undoubtedly energy. Energy by definition is that which acts, just as time is that which is. Energy is composed of two factors: it is the product of force by an extension. So emotion, the subjective aspect of energy, is also composed of two factors, and one of these is will, which is the subjective aspect of that mechanical quality which we call force. The geometrical aspect of force, and hence of will, as I have shown elsewhere,[2] is a surface. And the geometrical aspect of emotion and energy, energy being a mechanical concept, is volume. Will can be expressed, if this be so, in units of force, as so many dynes; or in units of surface as square centimeters; or in units of electrical charge. Every force in nature is the objective thing, which subjectively is will. Will, then, is everywhere that force is; and force is everywhere that will is. Power of action, or emotion, may then be expressed externally or objectively as energy, in units of energy, *i.e.*,

[2] "The Nature of Matter, etc.," pp. 19, 42.

ergs. But here again, in order to measure the power of action of an organism, its will, or emotion, the energy of the mentet only, must be measured. It will not do to measure the total energy of the cells of the body but only the energy of that very small part which is organized mentally. This is of course a very difficult thing to do and will probably be impossible. If, however, a method could be found to do it, then the emotion and will of any organism could be measured mechanically.

Vitality, then, which so far as its mental part is concerned is essentially the product of consciousness by power of action, or emotion, may be measured as time-energy in mechanical units of ergs-seconds, in place of mental units of consciousness and emotion. And since energy has the geometric aspect of volume and time that of extension, vitality can also be expressed in cubic centimeters-seconds, or as centimeters raised to the fourth power, as so much four-dimensional extension. This shows us that mentality is simply another name for matter, since matter is also, when geometrically considered, simply four-dimensional extension. But as matter is four-dimensional extension which has been warped or distorted so that it differs from that four-dimensional extension which is isotropic and symmetrical and unwarped and which we call the immaterial, so also the vitality which matter shows or is, is distorted, or mortal, and differs from the immortal form which is another name for the immaterial. Living matter, then, is simply matter so organized that all four of its aspects are shown at once. In it the mental aspect, which is concealed in the lifeless so that the latter exhibits only mechanical, electrical or magnetic aspects, becomes manifest. We can not create life until we can create matter; and to make living matter we shall have to find a means to organize matter by its mental aspects into a mental unity, rather than magnetically, electrically or mechanically. For one thing appears to the writer to be entirely clear, *i.e.*, that an organism is a mental unit. Its organization is then *sui generis;* it is not any of the physical organizations shown by dead matter. Any attempt to explain living phenomena without considering this most important fact seems to be foredoomed to failure. The organization in living matter is material but in its fundamentals is neither physical nor chemical, *i.e.*, mechanical, electrical or magnetic, but mental.

To return to our problem of measuring the mental field about every organism, it may be that the distortion about any one axis of space-time is necessarily correlated with distortion, to some degree at least, about the other three. If this should prove to be the case, and we could find the necessary correlations of the distortions about the different axes, then it might be possible to measure the distortion about the mental or time axis, not directly, but by a measurement of the accompanying distortion about the electrical or magnetic axes. This, however, is perhaps a remote possibility, although such correlating factors for the other aspects of matter are known; the specific inductive capacity being the factor correlating the mechanical with the electrical aspects, and the magnetic permeability the factor correlating the mechanical and the magnetic aspects of matter. The specific inductive capacity is the factor relating mechanical units or ergs-centimeters to the square of electrostatic units; while magnetic permeability relates ergs-centimeters to the square of units of magnetic pole.

We may conclude, then, that what we must seek to measure in biology is the quantity of life of the organism as an organism, that is, as a unit. And that this is, in human beings at any rate, and possibly elsewhere, only a very, very minute amount of the total vitality in the organism. The only possibility of

measuring it that the author sees is to find a means of measuring directly the organism's accompanying field of consciousness and will, if such a field exist about it, for unitary consciousness and will are the only properties of living organisms which are peculiar to them. Such a field, however, must exist if the theory of matter expressed by the author be correct, and organisms may act on other organisms through it. Search should be made for it for I believe its discovery alone can make biology an exact science and convert biological conjecture into certainty.

Finally, it is obvious that the essential and peculiar energy shown in living things is mental energy. In this sense we may speak of mental energy as a truly vital force and energy. It is just as peculiar a form of energy of living things as magnetic energy is the peculiar energy of a magnet or electrical energy of an electet or mechanical energy of a crystal. It is this peculiar and characteristic energy which accounts for all the peculiar and characteristic phenomena of life. For the characteristic phenomena of life are power of choice and action. This mental energy, however, is just as real, universal and material as is electrical, magnetic or any other form, for energy is probably always the same thing and we deal in its various manifestations only with different aspects of that thing. This mental energy can be measured just as soon as we make a delicate mentetometer. It will be expressed in ergs, when found, in the same manner as is expressed its other forms. The amount of such organized mental energy in any cell is probably only a very small proportion of the total, except possibly in very minute organisms. To measure it, therefore, will be difficult.

With the idea that there was in every living thing this peculiar form of energy, as long ago suggested and advocated by Rignano, I was not at first in sympathy. It seems to me now, however, that there is no escaping the conclusion, and in the conception sketched here and developed in my book on "The Nature of Matter," the exact relation of it to other forms or aspects of energy is pointed out. In my opinion it is the neglect to consider this peculiar form of energy which accounts for the difficulty many biologists have had in interpreting vital phenomena and for their differing opinions as to the nature of life itself. It shows that while every organism, including man, is a machine, yet controlling this machine as long as it lives there is a material organization of a kind which is at the bottom neither mechanical, magnetic nor electrical, but mental, which is the individual itself.

TALES THAT DEAD MEN TELL

By Professor JOHN HODGDON BRADLEY, JR.
UNIVERSITY OF MONTANA

SEVERAL million years ago the light of a new era was dawning on the continent of Asia. From the Arctic Circle to the tip of tropical India vast forests luxuriated under a friendly sky. Many a great beast stalked the depths. Safe in the matted branches, numberless bands of tree folk shrieked derision at the snarling enemy below. Here were the ancestors of many long-tailed monkeys and the tailless manlike apes, unconsecrated children of the jungle. Here too was the creature of destiny, alone blessed of all the horde. For Nature had dreamed a dream, and had chosen this one to make it real. Bright in the promise of the new day, the ancestor of man swung slowly toward his destination.

Slowly the land rose, the climate grew severe, the trees languished. The simian paradise became a purgatory, because the very existence of the tree dwellers was interwoven with the branches of their homes. Asia began to buckle in the middle as the Himalaya mountains were born. The ancestral forest was cut in two. Before the barrier rose to impassable heights, many monkeys and apes escaped to India, where their descendants enjoy life to-day in ancient comfort and safety. Others lingered too long in the northland. Slowly the mountains grew, the climate became colder and drier, the forest shrank. Cut from escape to the south, the bedeviled remnant of the happy horde met death. Some starved with the dwindling of the trees and tropical fruits. Others tried life on the ground. But here were the teeth and claws of bloodthirsty enemies, and many weaklings succumbed. It is not surprising that but one of all the forms survived, a lone victor in an unfair battle. But this was the creature of destiny whom fate had chosen to be the father of humanity.

The forerunner of man came down from the trees reluctantly and only as a last forlorn hope. He had been just a skylarking vegetarian, in an easy, friendly world. On the ground his old fruits were missing, food of any kind was scarce. The cold, dry climate was an increasing menace to his health and happiness. His teeth were too weak, his claws too dull to protect him from the powerful foes of his new environment. And he lacked the equipment for running away. The whole world was out of joint. His only friend was the latent power in his brain. He must learn to outwit his surroundings or die. He learned because in him was some of the stuff that men are made of.

Through many generations the apelike bodies of his descendants were slowly molded for life on the ground. Countless individuals, unable to conform to the new demands, perished. But slowly out of the survivors emerged the human body. Arms were no more needed to swing their owners from branch to branch, so they became shorter. Legs grew longer. Thighs straightened to bear the weight of the body. The great toe became greater, and lay parallel to the others so that the creatures could walk on the soles rather than the sides of their feet. Erect carriage was slowly acquired. Hands were freed from locomotion to become instruments of the mind. They lifted the burden of defense and food-getting from teeth and jaws. The teeth, no longer a vital necessity, degenerated, so that to-day the dentist fights a losing battle in the human

mouth. The power of the jaws waned. With the growth of intelligence, muzzle and brow ridges grew smaller; brain, skull and chin grew larger. Slowly the human face took shape.

With hands no longer tied to the branches, the precursors of modern man learned to protect themselves with clubs and stones. But this was not enough. Cold weather continued to creep out of the Arctic. Plenty of food and clothing was necessary to carry them through the long winters. They must turn hunters and track the great beasts to their lairs. The men of the dawn did this and more. They made the discovery which Remy de Gourmont called "the most characteristic act of genius of which mankind can boast." They discovered the use of fire, without which further progress would have been impossible. At last, before weapons, clothing and fire, the barriers of climate and foe were down. The early men were able to roam in all directions, to take up cooperative living, to invent articulate speech, to sow the seeds of civilization.

Such is the scientific story of the ascent of man. It is largely the product of imagination. No scholar would maintain the truth of its details, for decay has obliterated much of the tangible evidence of man's climb from the abyss. Yet no scientist doubts the broad truth of the story, the rise of man from apelike ancestors.

Whatever may be our prejudices, we can not take man out of the animal kingdom. It is not an insult to the spirit to admit that man is a mammal. Like other mammals he suckles his young and has a backbone, warm blood, hair, separate chest and abdominal cavities. It is rather a defect of the spirit to deny such an obvious truth. Among mammals the position of man is equally clear. He is certainly no close relative of the duckmole or the kangaroo because he neither lays eggs nor carries his young in an abdominal pouch after birth. But he does belong to the mammalian group whose young are nourished before birth by the placenta. Among these he is only remotely like whales, elephants, beavers, cats and cows. Whether we like it or not we must admit that he most resembles the apes. His legs, arms, feet, hands, teeth, posture, even his blood and his brain are strikingly apelike.

The similarity of man and ape suggests that both descended from a common ancestor. The rock record of the past goes a long way towards proving it. Although the truth about the progenitors of man is obscured by the mists of time, it is not entirely hidden. The bones of extinct men and manlike creatures, though rarer than precious jewels, are eloquent of the history of humanity. Some people deny the tales these dead men tell. But fossil men can not lie.

On the island of Java, along the banks of the Solo River, are rocks long known to contain the bones of fossil mammals. In 1890 the Dutch government sent Eugene Dubois to explore these deposits. Work continued for several years and large quantities of bones were unearthed. The fragments of a single specimen will be remembered long after its flimsy stuff has crumbled away. For the skeleton is that of the Java ape-man, perhaps the most significant discovery ever made in the rocky tombs of the forgotten.

Skull cap, left thigh bone and three upper molar teeth were all that had escaped decay. But these are enough to prove the former existence of a creature more like a man than any living ape and more like an ape than any living man. The skull was only two thirds as large as the skull of modern man. The size of the brain must have been between that of the highest ape and the lowest man. The brows were overhanging, the forehead low and flat. The nearly

straight thigh bone tells us that the creature was as large as a man and walked erect. The teeth were more apelike than human. Most authorities agree that the Java ape-man was more human than simian, although perhaps not in the main line of development to the men of the present. Marcellin Boule, the distinguished French paleontologist, and a few others believe him nothing but a large and special kind of gibbon. Whatever the truth may be, whether he was our granduncle or our grandfather, or just a glorified ape, the Java ape-man breaks down the barrier between ape and man. He is just the sort of creature that should have existed if ape and man share a common ancestor.

Though far below the lowest human of to-day in all the prized blessings of mankind, the Java ape-man may have ruled supreme in his day. And that day was scarcely more than half a million years ago, an almost negligible fraction of geological time. Since then humanity has traveled so far from the apes that the mere mention of a simian origin is disagreeable to many people. But evolution does not usually move at so rapid a pace. Sir Arthur Keith believes the Java ape-man an old-fashioned survivor of a former epoch, and that somewhere there existed a contemporaneous but still undiscovered race with more of the characteristics of modern man.

The intelligence of even the earliest human beings is the thorn in the side of the scientist in search of origins. Man, primitive as he was in the early days of the glacial period, was not the creature to die a fool's death. The Java ape-man was undoubtedly the victim of drowning. His bones were quickly sealed from the air by the river sediments, and preserved from decay. But his friends and relatives escaped such accidental embalming and died on the plains or in the forests where their bones turned back to dust. Death by drowning before the days of navigation must have been exceedingly rare, and most other deaths robbed time of its record. When early men learned to avoid drowning and to bury their dead in the earth, they learned to destroy the most significant proof of their existence. For bones rot unless tightly sealed from all the cankerous cohorts of decay.

So it happens that the remains of the Java ape-man stand alone in their antiquity. From time to time new discoveries have been made which threatened the isolated glory of the bones from Java. But the new finds proved to be either not so ancient as first thought, or too poorly preserved to tell a clear story. Some of them were found to be not human at all. Recently the bones of a creature resembling a human child were unearthed from a rather old deposit in Australia. When a complete description of these remains has been made, science may know whether or not it has found a close relative of the creature from whom modern man was descended. The skeleton is undoubtedly not old enough to be the actual ancestor of the men of to-day, and it is too much like an ape to be classed with even the lowest of men. So too in other continents; North America, South America and Africa have yielded no fossil traces of undoubted men comparable in antiquity with the fragments from Java.

In Europe the bones from Piltdown, England, have long been discussed. The skull is clearly that of a manlike creature, but farther along the road to true humanity than the Java ape-man. The jaw is apelike, and some authorities believe it the jaw of an ape that resembled the chimpanzee. If the skull and jaw belonged to the same creature, the Piltdown man was primitive, a true ape-man, who lived perhaps one hundred and fifty thousand years ago. Though one of the oldest of Europeans, he does not deserve

the name of "dawn man" which science has given him. That name belongs to the more primitive man of Java.

Even older than the "dawn man" of England is the man of Heidelberg, whose position as the very earliest known European can not be contested. Although he bequeathed his lower jaw to the world and nothing more, he has the unique distinction of being the only fossil man about whom all authorities agree. He lived in a warm age, probably between the second and third advances of the great continental glaciers of the Pleistocene period. The massive, chinless, apelike jaw with its primitive manlike teeth is just what one would expect of this remote creature. He was neither true man nor true ape, but a transition type with the characteristics of both.

Possibly the direct descendant of the Heidelberg man was the man of Neanderthal, the best known of all fossil men. Several specimens from various localities in western Europe tell the story of this widespread race. The mark of the beast was still heavy upon the Neanderthals. They were little more than five feet tall, and walked on short limbs with an apelike stoop. Their skulls were large, and heavy brow ridges met across the forehead. Chins retreated, teeth projected, heads were thrust forward. Brains were large but primitive. Despite all this the Neanderthals were men, the first of the cave dwellers. For they knew the use of fire, and made tools and weapons of fine workmanship. But more than this, they buried their dead with reverence and proved that in their hearts was stirring the first faint feeling that death does not kill all. They ruled over Europe for many thousands of years. Near the close of the last glaciation they were driven to their doom by the first of the moderns, the stronger and more intelligent Crô-Magnons. This happened perhaps twenty or twenty-five thousand years ago. From then to the present, the story of man is an unbroken chain.

It is unfortunate that the chain is not complete in back of the coming of modern man. With the available facts science can not know the exact history of mankind. No primitive fossil man thus far discovered can be the direct ancestor of the first modern man. Yet the evidence is conclusive that creatures once lived who were neither apes nor men, but both, and that with time these creatures became more human. Their bones all tell the same story of the lowly origin of man, and their bones can not lie.

To-day man is far removed from any living ape, for man has gone forward and ape backward. Yet man is also far from the gods. The ego should be pleased to see man the glorious result of infinite striving by apelike ancestors, rather than the degenerate descendant of a god. But Nature did not consider our pride when she made us. She cast our bodies in the mold of an animal. No amount of denial will take the beast from our bones. The best we can do is to try to rout him from our spirit.

INSTINCT AND MAN

By Dr. MAX SCHOEN

CARNEGIE INSTITUTE OF TECHNOLOGY

THE study of the nature and significance of instinct in man is far from being merely an academic question. The problem is of fundamental significance, since it deals with man's inborn powers, the nature of the sources and mainsprings of human behavior. Its practical importance is seen most clearly in the popular scientific literature of the last decade dealing with the implication for human welfare of the doctrine of heredity and of the findings of the so-called intelligence test. In this literature we are told that biologically and psychologically the fate of man, from whole races to single individuals, is predetermined by what he brings with him into the world, that is, his instinctive equipment. Two important facts seem to have passed unnoticed in these discussions: first that biology and psychology, although closely related, approach the study of what is man from different angles; and second that biology can speak more authoritatively about heredity than can psychology about instinct. Biology is concerned exclusively with the nature of the heredity mechanism. It has little to say, although it may imply much, as to the nature of the finished product of heredity, the born infant. When biology has determined how the new human organism is formed from the germinal material and what goes on in its embryonic stages, it has finished its part of the work. The rest is for psychology to ascertain. But whereas biology has attacked its problems experimentally, psychology has in the main been guessing as to the basic nature of the material with which it is concerned. With the exception of the work done by John Watson on infants, there is no reliable evidence whatsoever as to the native state of the human material whose education constitutes the main problem of society. William James defines instinct as "the faculty of acting in such a way as to produce certain ends, without foresight of the ends, and without previous education in the performance." So far so good. But what evidences does he cite for this clear-cut, dogmatic statement? His illustrations of the definition are all taken from animal life, and these from the animal adult, and it is upon this dubious foundation that he erects an imposing structure of human instincts. William McDougall's standpoint on instinct, the influence of which has been wide and varied in education, industry and social psychology, namely, that it is "an inherited or innate psycho-physical disposition which determines the possessor to perceive, and to pay attention to, objects of a certain class, to experience an emotional excitement of a particular quality upon perceiving such an object, and to act in regard to it in a particular manner, or, at least, to experience an impulse to such action," simply states in so many complicated and mystifying words that a living organism will probably do something when confronted by a situation, in other words, that living organisms possess life. His array of specific instincts consists of an enumeration of adult activities for which no parallel whatsoever exists in the infant before the period of learning, which means the very hour of its birth. If instincts are native behavior, this native form should be readily recognizable, as in the case of some lower forms of life, insects, for instance, or there is no reason for calling them inborn. If they appear subsequent to the inborn period, what justification is there for

calling them "instincts" rather than habits? But besides the simple reflexes, no act that even approximates to what is called an instinct is discernible in the new-born infant. To read the animal, and even that belonging to the lowest stages of life, into man, is to forget the facts of progressive evolution, while the practice of inferring the presence of instincts in the new-born infant from more or less developed behavior of a postnatal period is to fail to take account of the subtle effects of the environment upon that most sensitively organized machine in existence, the human offspring. The education of this organism begins on the day of its birth, and in its early days every factor in its environment produces an effect upon it the significance of which can be ascertained only by the closest experimental observation. Certainly all the reliable evidence that we possess from Dr. Watson's experiments is against the orthodox instinct creed and in support of the conclusion that there are no instincts as such, and that "everything we have been in the habit of calling an 'instinct' to-day is a result largely of training—belonging to man's *learned behavior.*"

What, then, are we to understand by instinct? And what is the answer to the question whether or not there are instincts in man? Instinct is the scientific trade name for native behavior, or behavior that is present at birth, and which therefore antedates and precludes learning. The study of comparative psychology suggests two causes for the contentious atmosphere that pervades the realm of instinct. One of these causes is the failure to consider instinct from the comparative point of view as an evolution and not a fixed state. The other cause is a like failure to recognize in the make-up of man the vestiges of his animal ancestry, namely, that his psychological constitution retains the landmarks of his biological evolution.

Organisms belonging to different stages in the evolution of life possess native behavior, the fundamental nature of which varies in complexity and flexibility. The simple structural organization of the ameba determines the extent of the world in which it lives as well as the scope of its needs and consequently the scope of its activities. Its behavior is no more diverse than its machinery demands. In contrast to this simple existence of the ameba is the immensely complex life of man, created by a highly differentiated and specialized structure of sense organs, muscles, limbs and nerve tissues. The more highly organized life becomes, the wider is the scope of its activities, since the world in which it lives becomes more extended and varied. Evolution of life represents a spectacle of a gradually unfolding universe from vague, homogeneous chaos, to systematized, heterogeneous order, with a corresponding increase in complexity and specialization of behavior suited to meet the widening expanse of the realm of life. The vague, undifferentiated world of the ameba is met by similarly vague, undifferentiated movements. The very definite, differentiated world of man is reacted to with a large number of definite, specialized actions. The world of the ameba is not the world of the insect; that of the insect is not that of the vertebrate; and that of the vertebrate is not that of the mammal. And the behavior of these organisms is in keeping with the world in which they live.

Running parallel with the increase in the complexity of the environment and of behavior, we find an increase in the flexibility of the behavior. Flexibility means the degree to which the behavior is subject to the moulding influences of the environment. Moulding means possibilities for variation, and therefore, where the possibilities for variation are largest, there we also have the greatest scope for meeting the widest variety of situations.

This brings us to the heart of the instinct problem. Instinct as native behavior can not possibly mean the same

thing for different forms of life. The instinct of the insect is not the instinct of the vertebrate, and that of the vertebrate is not the instinct of the mammal. The difference lies in the degree to which the native behavior is subject to habit formation, or, in other words, the degree of variability of the organism at birth. All native behavior is modifiable from two angles: first, in the situation that elicits a certain behavior, and, second, in the kind of behavior that a certain situation evokes. Thus, as a result of training, a large number of varied stimuli can be made to evoke one and the same specific response, or a number of varied responses may be aroused by the same stimulus. Both these factors imply the number of habits that the animal can form, and the degree to which any one habit deviates from the native behavior from which it springs. And it is the original state of the native behavior that determines both the number of habits that can be formed and the degree of habit formation. When the native material is least variable, the possibilities for the double aspect of habit formation are most limited, that is, the animal can form but few habits, and even the few habits that it can form vary but little from its native reactions. And where the native behavior is most variable, as in man, the scope for habit formation is widest, while the habit resembles nothing that is present in the original behavior. Now variability is in inverse proportion to definiteness of original behavior. Where specific forms of behavior exist at birth, the possibilities for modification or habit formation are most limited. In such cases we can speak of the presence of specific instincts. But in the higher and particularly the highest forms of life, where differentiated forms of native behavior are present in a slight degree, or not at all, we can not speak of instincts, but only of general tendencies to behavior. Native behavior is an evolution from more or less specific native acts to a general mass of random movements which gradually become split up into a large number of specialized single habits. Where native behavior consists primarily or altogether of random movements, there are no instincts, since instinct means inborn specific action, while in man every specific act is an acquired property, formed out of the general chaotic mass of native tendencies. The native behavior of man becomes useful only when it becomes differentiated into habits. A habit is not even a modified or inhibited instinct, since a specific human act resembles in no way anything that is natively present. We can speak of a modified instinct only where, in the finished act, there is easily discernible the presence of the unmodified, native root to which the habit can be definitely referred. There is nothing in the infant that in any way approximates to such developed forms of behavior as curiosity, pugnacity, imitation, etc., which are usually classed as instincts. In fact, the standard criterion for instinct, namely, an act common to a species and somewhat perfect on first appearance, is inapplicable to human behavior. Birds will fly when anatomically ripe, and all birds of a certain species will fly alike. But a child develops an individual manner of locomotion, and it is extremely doubtful, and even improbable, that it would ever walk, were it not for the presence in the environment of factors that induce it to learn to walk. The vocalization of an insect is altogether native, that is, an instinct. But the song of the bird is influenced by the condition in which it is reared. A sparrow reared with canaries will not sing like a canary, but neither will it chirp like a sparrow. The song of the sparrow is thus part native and part acquired, with the native element readily discernible in the finished product. But the speech of man is acquired in form and substance, and no

native element is present in it excepting that it is based upon the native tendency to produce sounds. But the native element is far removed from that which characterizes the insect or even the bird, since the human infant can acquire not only one form of vocalization, but many, and can keep on acquiring them more or less perfectly throughout his lifetime.

We note, then, that instinct is not an invariable something and therefore can not be applied indiscriminately to all living forms. If by instinct is meant anything resembling the native behavior of the insect or even that of the bird, then man certainly has no instincts. He is a bundle of habits, and even these are continually subject to modification. There is nothing predetermined or inflexible in his psychological make-up. If by instinct is meant simply native behavior, then the insect has instincts as such, the bird obeys instinctive tendencies and man possesses a general urge to behavior. The insect comes into the world quite a finished product, the bird less so, and man least so. The insect is born; man is made.

This interpretation of instinct is supported by biological and psychological facts regarding the nervous system, that is, its evolution and its functioning. The evolution of the nervous system from a simple to a highly complex structure is a progressive growth in plasticity of nervous organization, and hence of increased possibilities for modification and control of behavior. Concomitant with this growth in complexity and plasticity runs a higher and higher functioning, from the mechanical reflex to the intelligently controlled and directed voluntary act. The domain of mechanical behavior thus diminishes gradually, until it shrinks into insignificance with the rise of higher nerve centers. In the simplest nervous system, impulses are switched over immediately from receptors to effectors, resulting in trigger-like behavior. In the highly evolved nervous system the impulse is retained in a central station where its final destination is decided upon. The nervous system, beginning as a mere transmission mechanism, becomes a regulating and controlling and deliberating organ. Instincts as such are present or absent in direct proportion to the complexity and the concomitant variability of the behavior. In the simple nervous system, behavior approaches closest to the mechanical reflex, and there we have instincts. In the complex nervous system, behavior gets to be more and more of the nature of directed, voluntary action, and consequently farthest removed from instinct.

We now turn to an examination of another significant problem; namely, does the fact that man has no instincts justify the corollary drawn by Dr. Watson "that there is no such thing as an *inheritance* of *capacity, talent, temperament, mental constitution* and *characteristics?*" This claim of Dr. Watson's is not at all supported by experience and experiment. In fact, in making this claim, Dr. Watson contradicts himself since he admits inherent variations in "structure (including in structure, of course, chemical constitution)."

The structures in which human beings differ are sensory, muscular, glandular and nervous. And *talent, intelligence* and *temperament* are matters of *sensory, muscular, glandular* and *nervous capacity.* Capacity means the readiness with which these structures will permit one to profit by training along a certain definite line, or the degree to which these structures are subject to modification in a certain direction within a certain given time. Thus human beings, whose behavior is essentially acquired, nevertheless differ from each other in degree and type of *acquirability,* so that although man is the most flexible of organisms, we nevertheless find in him a variation at the pinnacle of flexibility,

similar to the variations we found to exist between man and the forms of life below him.

Let us take capacity for musical performance as a case illustration. Whatever the musical performer can do, from the merest amateur to the supreme artist, is an acquired or learned accomplishment. But even under equally adequate instruction accomplishment will vary, because individuals have constitutional differences in those structures that function in musical talent. What are these structures?

Musical talent as a whole consists of a cluster of specific talents of the nature of fundamental capacities. One of these talents has its seat in the very texture of the hearing organ. On the native state of this organ depends the production of such essential artistic effects as correct intonation, delicate nuances, fine tonal timbre and minute differences in tonal durations. Thoroughly standardized tests indicate the marked variations that exist among individuals in native power to respond to these factors. In pitch discrimination, for instance, we find a variation from those who recognize a pitch difference of 1/200 of a tone to the almost completely tone deaf, and no amount of training will turn a dull discriminator into a sharp one.

Another specific talent that functions in musical artistry is technique, by means of which the performer is enabled to make himself articulate. Technique is the ability to express exactly what one wants to express in the way one wants to express it. It is perfectly possible for a person to have keen pitch discrimination and yet play in false intonation simply because the muscles refuse to obey the command of the ear. In other words, technique is in the last analysis largely a matter of muscular fitness, and some muscles are by nature more accurate, precise, speedy than others.

Again, it is not mere chance of circumstance that induces one person to become an artist, another a scientist and a third a philosopher, nor is it mere whim that decides whether one is to become a musician or painter, a physicist or biologist, a psychologist or metaphysician. The more we learn about the endocrine glands, the more convinced are we that temperament is not mere artificial posing, but is something due to differences in vital physiological processes that color and decide the individual's interests and outlook. But the recognition of the existence of native aptitudes, temperaments and mental inclinations does not imply the existence of instincts, and Dr. Watson's extreme point of view in denying talents and aptitudes is more sound scientifically than the somewhat fatalistic instinct doctrine. The marked musical talent of the child is quite a different matter from the pecking instinct of the chick or the flying of the bird, although both are structurally conditioned. The talent needs very careful fostering and can most easily be distorted and ruined, while the chick will peck and the bird will fly unless the one loses its head and the other its wings. Likewise there is nothing fatal or predetermined in temperament, for although its basis is native, its ultimate functioning is environmentally determined, as is amply demonstrated by Dr. Watson's experiments with conditioned behavior in infants. One infant might be born with a greater propensity for anger or fear responses than another infant, nevertheless what arouses fear or anger or the specific form that the responses assume is controlled by nurture and not by nature.

"Man," says J. Arthur Thomson, "has his reflexes and a little instinctive behavior; most of his activity is either intelligent, or was originally intelligent, but has become habitual; the point is that, if occasions arise, man may instantaneously pass from a lower level to that of rational conduct." And man is able to do this in the main because he is least

hedged in and limited by his native equipment. Man is the most intelligent of organisms because he can meet most adequately and most readily the largest variety of most complex situations. In other words, he is most intelligent because he is most educable, his greater educability being due to the plastic state of his native behavior. Intelligence thus means degree of variability of native behavior. Where the original behavior is least modifiable, intelligence is least present, and where it is most variable intelligence functions in its highest form. And since all behavior, including even the simplest reflexes, is subject in some degree to the influence of education, intelligence of some kind functions throughout the entire scale of life until we reach its maximum degree in man. Intelligence does not rule out instinct, nor does instinct exclude intelligence, but both are two phases of one and the same process, namely, adjustment to a situation. The evolution of intelligence is concomitant and coextensive with the evolution of instinct, in that the higher the form of instinctive behavior, the greater is the intelligence. To put it differently, native behavior is instinctive behavior, while acquired behavior is intelligent behavior. But that which is acquired arises out of that which is native. Hence, intelligence is as native as is instinct, since intelligence is conditioned by instinct. That is, that which is acquired and that which is native are basically one and the same, as the acorn and the oak are one.

When we examine the relationship that exists between mind and behavior, we reach a similar conclusion as to the identity of instinct and intelligence. The nervous system is the machinery of adjustment. An adjustment involves the functioning of two factors, a nervous and a muscular activity. The nervous activity consists of impulses of various degrees of complexity, depending on the complexity of the central nervous system: the more complex the nervous system, the more numerous and involved are the impulses. And it is the nature of the impulse that determines the type of the muscular activity. Simple impulses lead to simple behavior, and complex impulses result in complex behavior. Thus, when an impulse coming from any sense organ reaches the spinal cord, it may either travel directly and immediately to a muscle *via* a motor nerve, or it may be relayed to some higher nervous center. Organisms with a rudimentary nervous system, those lacking higher nervous centers or those in whom the higher centers exist in but an elementary form, are capable of but simple behavior that approaches the state of reflexes. The responses of such organisms to a situation are trigger-like, immediate and mechanical, which means least educable or intelligent, since reflexes are the least educable elements of animal behavior. Animals in whom the central nervous system is more highly evolved, or who possess higher nervous centers, manifest a more complex form of behavior, and their responses are more deliberate, more educable, or more intelligent. It seems then, that intelligence and nervous processes are identical, and likewise intelligence and deliberate or delayed behavior are identical. Intelligence is then definable as delayed behavior, and delayed behavior is educable behavior. The longer that behavior is delayed, the more intelligent it is, which means in turn that the number of nervous processes involved is greater before the final adjustment to the situation takes place. If instinct is native behavior, it is clear that the end result of delayed or intelligent behavior is as instinctive for higher forms of life as is immediate behavior for lower forms of life, and there is no ground for drawing a distinction between an instinctive act and an acquired or intelligent act. We may speak rightly of degrees of intelligent behavior, or, which

amounts to the same thing, of degrees of instinctive behavior, since all behavior is intelligent in that it is more or less educable, and since all behavior is instinctive, in that the native element determines its educability. In man instinct makes possible the most intelligent behavior, in the insect the least intelligent behavior. In man, certainly, no act can be said to be either instinctive or intelligent, but is as much instinctive as it is intelligent, since it is the state of man's instinctive behavior that constitutes his intelligence.

The common practice of ascribing a dual nature to man, the one human and the other animal, owes its origin and persistence to the false juxtaposition of instinct and intelligence discussed above. On the basis of this mistaken notion repeated attempts have been made to explain and often to justify the existence of many social and individual evils, while numerous plans have been proposed whereby the instinctive "beast in man," constituting his lower nature, might be defeated by the exercise of his higher nature, or his intelligence. Man, it is said, is by nature pugnacious, grasping, envious, jealous, and at the same time also sympathetic, gregarious and loving. Hence his make-up is not only dual, but mutually antagonistic and contradictory. The function of intelligence must therefore be that of serving as a moral guardian and censor over the instinctive brute, to refine it and to keep it within proper and respectful bounds. Hence the horde of maxims, admonitions and preachments for the control of what is called human nature, the sum and substance of which is summarized in the notion that whereas instinct can not be eradicated it can at least be modified and controlled. This doctrine is the psychological counterpart of the theological tenet of original sin, and, like the latter, has been utilized to justify wars, industrial strife and social and political aggrandizement.

But a preachment is never against an instinct, something that an individual does natively, but always against some individual or social habit. Human beings love nothing by instinct and hate nothing by instinct, but acquire their likes and dislikes in a subtle, but nevertheless detectable, manner. A child can be taught to hate or to love any person or object, and it can be turned either into a pugnacious or peaceful creature, depending on how and where it is reared. Mother love is no more an instinct than is love for one's country or family, a painting or a house. The movement for the abolition of war is not an attempt to eliminate or suppress a pugnacity instinct by intelligence, but to change vicious and destructive social habits into constructive ones. This changing conception of the relationship between instinct and intelligence not only shows up man in a more hopeful light, but also reveals human nature in its true state; namely, that man is a creature of habits, a creature of intelligence, and that his nature is whatever it is made to be by education. The evolution of intelligence and the evolution of instinct constitute a single process, instinct being but another name for intelligence, and intelligence another name for instinct. The highest form of instinct is the highest form of intelligence, and the lowest form of intelligence is the lowest form of instinct, and vice versa. Instinct and intelligence are inseparable. Whatever an organism does instinctively is a sign of its intelligence, and whatever it does by intelligence is an indication of its instinctive state. There is not a single act of behavior that man performs that is either exclusively intelligent or exclusively instinctive, but it is always instinctively intelligent.

Intelligence, then, means the degree of the variability or educability of native behavior. Consequently, just as instinct and intelligence are one, so are intelligence and education. A man displays

his intelligence by what he can do, and what he can do is the result of his education. Man is the most intelligent of animals because he is the most educable, and there is no other indication or measure of his intelligence than his education, or what he can actually do. An infant at birth has no more intelligence than has a bird, although we know by experience that the child will develop more intelligence than will the bird, and we therefore infer that the child has greater intellectual capacity than the bird. The notion of capacity is but an inference from actual accomplishment, but remove accomplishment and you know nothing about capacity. We know of no capacity, as such; all we know of is accomplishment. When we say that accomplishment is in proportion to capacity we are defining the known in terms of the unknown, certainly a reversal of scientific procedure. It may be objected, however, that there must be such a thing as capacity, since for one and the same person accomplishment will vary with varied training, which means that one type of training brings out one's capacity, and another type of training does not. But this simply means that accomplishment depends on the conditions in which the person finds himself, that one set of conditions will bring out one type of accomplishment, another set of conditions a different type of accomplishment, which is only stating that man is a most variable, or educable creature. It may be argued further that often one's accomplishment does not measure up to one's capacity. But this is again only stating in ambiguous terms what is very evident; namely, that experience teaches that accomplishments vary with conditions.

Does the above contention deny the existence of native individual variation? Not at all. Human beings vary fundamentally in muscular and organic structure and texture, and hence in the functions and powers of these structures. But this difference in structure only means a difference in susceptibility to different kinds of environment, condition or training. One kind of temperament, for instance, will be more responsive to a certain kind of influence than will another kind of temperament. The objection to the notion of capacity is its flavor of fatalism or predeterminism, while we know by experience that so long as he is alive, man is modifiable, only that with the advance of years the structure becomes more and more set and less and less variable. But man's power for modification is never completely exhausted, and hence he has no capacity as such, but only possibilities for accomplishment or educability.

To summarize, we find that man is primarily and essentially a creature of education. The education of the human organism begins at birth and continues throughout life. However, human beings differ in intelligence since they differ in structure. But intelligence is not structure but what happens to the structure through education. The structure influences the kind of effect produced by a certain education, and it is for this reason that the same environment will produce different effects upon different individuals. But this does not mean that structure limits education as a whole, but rather the kind of an effect and how much of an effect a certain kind of education will produce upon him within a certain given time. It is therefore education that counts, and not capacity. Man's sole capacity is to be influenced differently by education, and his intelligence is to be ever subject to education.

THE FUTURE OF SCIENCE

By Professor CHARLES A. ELLWOOD

UNIVERSITY OF MISSOURI

SCIENCE is one of the most commonly misunderstood parts of our culture. The average citizen maintains toward it either a negative attitude or only a half-intelligent attitude. The scientific world is in part responsible for these misunderstandings. It is time that the scientific world go to the mat to straighten out these misunderstandings; for they are rooted in the disagreements among scientists themselves. Science is the acknowledged basis of our material civilization. The question at issue is, Can it become also the basis of our spiritual civilization? If so, in what sense?

Perhaps it is unfortunate that the word "science" ever came into our language; for in recent years orthodoxies have been growing up about the word which tend to narrow its meaning unduly. The word originally meant simply "knowledge"; but by common consent, knowledge is not knowledge in the social and cultural sense until it is tested and verifiable. The knowledge which comes by individual experience is so often faulty and fragmentary that only the knowledge tested by the experience of many, and then only by methods which minimize emotion and prejudice, is found in the long run to be trustworthy, and worthy to be called "science." It is "science" in this broad sense of "tested knowledge" whose rôle in civilization we wish to discuss. We shall be only incidentally concerned with science in any narrower sense.

In this broad sense of "tested knowledge" science is fundamental in the process of culture development. Man has always lived by knowledge; and he can live in no other way and remain human. Knowledge is the basis of all his successful adjustments except the few made upon the animal levels of instinct, emotion or accident. It is also the chief means by which man corrects his errors. Adequate knowledge means the elimination of error and success in making adjustments. It is therefore the great source of all mastery over nature, and we believe that in the future it will be the greatest means of controlling human nature and human relations.

The growth of tested knowledge, while it is in civilization the pearl of great price, has been very slow in our human world. It is often said that all primitive man's conceptions were theological and mythological. But this is a mistake. Some tested knowledge regarding the arts of life accompanied the development of those arts from the very beginning. Then, too, it is wrong to put in absolute opposition the magical and theological with the scientific. What we call the magical and theological even among the most primitive peoples often contained elements of tested knowledge. But primitive man had no means of testing his knowledge except by the crudest methods, and therefore what he believed to be knowledge was usually heavily laden with errors. Moreover, uncivilized man had no means of accumulating knowledge except oral tradition. Again, nomadic life, war and other social disturbances in early history interrupted the transmission and accumulation of knowledge. Even after the invention of writing progress in the accumulation of tested knowledge was very slow. The Egyptians and Babylonians made a

beginning and, along with the Greeks, invented many methods of measurement. But even among the Greeks the amount of tested knowledge was very small, if judged by our standards. It was not until the invention of printing in the fifteenth century and the nearly simultaneous invention of certain "instruments of precision" that tested knowledge began to accumulate rapidly and to receive wide-spread diffusion; and it was not until the seventeenth century, the "century of genius," that the scientific movement got fully under way.

Science, therefore, has been the latest phase of culture to receive development, and it seems at first glance absurd to conclude that science is bound to dominate all the other phases of culture. But if we understand the nature of man and the nature of science we will see why this is so. Man is an animal that lives by experience and by what he learns from experience, rather than by ready-made reactions furnished by his germ plasm. Science is the tested knowledge that comes from experience, by using any and all methods which will reduce to a minimum errors of judgment. It is experience tested, verified and universalized. It must lie back, therefore, of every art and it must sit in judgment upon every human mood and upon every form of human conduct. It is, in brief, organized intelligence; and while man can not live through intelligence alone, he will be successful in his living in proportion as he is guided by the accumulated and organized intelligence of mankind. Tested knowledge is, therefore, if our civilization continues to develop, destined to work revolutions in all departments of human thought and action and to become the guiding element in the culture of the future. But if science is to assume this function, then it can be no narrow discipline, hemmed in by orthodoxies and traditional methods; it must itself become a movement toward knowledge of all reality, and take all verifiable knowledge for its province.

Yet the scientific movement still hesitates thus to broaden its scope. Elsewhere the writer has said:[1]

> Like all other phases of culture, science has been subject to all sorts of aberrations. Like all of culture, it has proceeded by trial and error. . . . Even during the nineteenth century science remained relatively undeveloped. It would be fair to say that it remained immersed in its beginning tasks, the exploration and understanding of physical nature, and scarcely arrived at seriously undertaking the exploration and understanding of human life itself. Indeed, there are still many who hold that science can concern itself only with the material and the physical; that it must rigorously exclude from its consideration the psychic or the mental. Evidently science still remains strongly influenced by metaphysical and personal prejudices. It has not yet, at least in a majority of scientific men, attained to the completely open mind.

"Behaviorism" in psychology and sociology illustrates the truth of those statements, for behaviorism in its pure form aims at the total exclusion of the mental or psychic from the field of human science. It, therefore, would exclude a part of reality from the attention of science. Yet behaviorism has become very popular among the younger psychologists and sociologists. In spite of its repudiation by the older psychologists, and even by some of our most eminent biologists, most of the younger psychologists to-day are making haste to climb into the bandwagon of behaviorism. Yet it is manifestly a hang-over from the nineteenth century conception of the nature of science and of scientific method. The scientific movement instead of showing a tendency to take all verifiable knowledge for its province would appear to be going to-day in the opposite direction, or at least to be keeping close to nineteenth century scientific traditions. It must be granted that this is the present trend, and moreover that

[1] "Cultural Evolution, A Study of Social Origins and Development," pp. 246–7. The Century Co. 1927.

this trend tends to become established as an orthodoxy. It may even be granted that so far as the mechanistic method and point of view in science succeeds in obtaining tested, verifiable knowledge, it will command respect and become established. What right have we to expect that science will free itself from restricting orthodoxies and will expand its scope? The answer is that it may not in our time, because orthodoxies when once established in any line of thought are hard to get rid of; but that the probability is that orthodoxies which restrict free inquiry in any line will be outgrown in time because history is a learning process. Man, as we said, is an animal that lives by experience, and science is at bottom tested, verified and universalized experience. This is why it is useful to man, and we may be sure that any attempt to make it anything less will fail in the long run. This is also why we may be sure that any narrow behaviorism in the human sciences will prove to be but a passing fad. What man desires and needs is tested and verifiable experience along every line. But if the whole field of tested and verifiable knowledge be given to science, then what effects may we expect it to have on the other phases of culture, and what new trends in science may we expect to develop?

In the sense of tested knowledge, science may be compared to light in the physical world. It illumines all objects and shows the path of safety as well as dangers. It enables us, therefore, to descry practical values. While it can not furnish us with motives, it may modify our motives. It can even indicate to us possible consequences and so in part reveal the future. It may therefore reveal to us our responsibilities, and become a basis for our faith and hopes as well as for our fears.

All this is equivalent to saying that scientific knowledge has a vital bearing upon both our morality and our religion. But this is denied by both the scientific and the religious dogmatist. Science, they say, can take no account of moral and religious values. But these are the very values upon which science in the sense of tested knowledge does cast its light. Let us at this point content ourselves by carrying out our figure. If we compare science to light, we may well compare religion to vision, not of course the vision of immediate things, but of the remote, the future and the unseen. So Professor Whitehead says,

> Religion is the vision of something which stands beyond, behind, and within, the passing flux of immediate things; something which is real and yet waiting to be realized; something which is remote possibility and yet the greatest of present facts; something that gives meaning to all that passes and yet eludes apprehension; something whose possession is the final good, and yet is beyond all reach.

Now just as physical light is necessary to physical sight, so the light of knowledge is necessary for that imaginative vision which gives rise to our religious faith, if we wish that vision to be sane and true and our faith a reasonable one. Thus may tested knowledge become a foundation for religious faith and science become a more and more dominating factor in the religion of the future. To say that "religion and science are mutually exclusive terms," and that "no union between them is possible" is, therefore, as gross a blunder as to say that knowledge and faith are mutually exclusive terms and have no interconnections.

Even closer is the bearing of science upon morality. If science is tested knowledge, then it should help us to discriminate values; its light should show us the way of safety, not only in the physical world, but also in human relations; not only for the individual, but also for nations. Tested knowledge will not only show us the way of physical and mental health—it can also show us the way of harmony, efficiency and mutual helpfulness in human relations.

Thus right and wrong, in a relative rather than an absolute sense, become scientific categories.

But here we must see also the limitations of science. The light of tested knowledge can not furnish us with motives, though it may make our motives intelligent. Value is a creation of mind, and attaches to objects and situations because of some fundamental human desire. Science can show us the way of bodily health, for example; but if we prefer death, then the way of health will have no value for us. Again, science can show us the way of harmony in human relations, given normal human desires and wishes; but if some of us prefer conflict to peace and harmony with our fellow men, then the way which leads to harmony will for us appear to have no value. To be sure, science may show us the genesis and even the danger and futility of some of our desires; but it is evident that the values which science helps us to discriminate must be practical and relative rather than absolute. The values of science are values only when we postulate the values of common sense, such as that life is better than death, that health is better than disease and that success in life adjustments is better than failure. But if morality is fundamentally a social matter, as practically all ethicists now recognize, then the social sciences must be the chief basis for a science of ethics.

But we are told that science is limited strictly to quantitative measurements and can have nothing to do with the social quality or value of our acts, and so nothing to do with morality. We are further told that more and more scientists are limiting themselves to what can be measured; that scientists are placing this limitation voluntarily upon themselves, and that science is naturally and necessarily what scientists say it is. This is the position of Dr. C. E. Ayres in his book, "Science the False Messiah." It is also the position of not a few philosophical and religious thinkers, who seem to find in this limitation of science the solution of many of their difficulties.

One obvious reply is that scientists themselves are divided. The "orthodox" scientists, as we may call them, would apparently limit the field of science to the measurement of objective conditions and the formulation of laws in such relations. They would not recognize the subjective or the world of values as within the field of science. Other scientists, however, do not hesitate to include such values, for example, as health and wealth within the scientific field. Indeed, the whole science of economics has been built upon the concept of economic values. Inasmuch as our social life is a life of values in all its phases, and is made possible only through the exchange of experiences between individuals, any study of it except in the most superficial terms necessarily must take the experiences and valuations of individuals into account. Thus far, in other words, the social sciences, whether they discuss markets, wars, governments, religions or other institutions, have been written in terms of human experience, and so in terms of value. It is for this reason that some, like Dr. Ayres, would deny the name of science to such studies, no matter how carefully they are made.

Here again we see the danger to clear thinking which may inhere in a word. The real question is, of course, not what meaning we should attach to the word science, but whether we can get tested, verifiable knowledge in the world of our subjective and social experiences, and so in the world of values. Hardly any one would say that we do not have tested and verifiable knowledge as regards health, though health is obviously a value; and he would be very rash who would say to an economist that we have no tested knowledge as yet regarding wealth and economic values. Moreover, this tested knowledge does not consist

always, or even in a majority of cases, of quantitative measurements. Quantitative measurements, indeed, are increasingly sought for by students in these fields; but they themselves would be the first to acknowledge that quantitative measurements in these fields are much desired because they are largely lacking, even though our knowledge of these fields in a general way is considerable.

Here questions as to scientific method naturally arise. What are the most fruitful methods of obtaining verifiable knowledge in the social sciences? Auguste Comte said that it was the historical method, but the historical method is obviously almost wholly devoid of quantitative measurements. Then there is the method of "the participant observer," which is one element in the historical method, and which can tell us so much about events and the behavior of groups, without again quantitative measurements. Then there is the method of the interview and the questionnaire, which can tell us so much about social behavior and its motives. Even the method of statistics, which aims at quantitative measurements of social phenomena, obviously depends upon the methods of the interview and of the eyewitness. If these latter methods are worthless from a scientific point of view, then so also the method of statistics. Our United States census, for example, is valueless if the method of the interview is not to be trusted, because the census largely is made up of the results of interviews. It is scarcely necessary to discuss the question of scientific methods further. These illustrations are sufficient to show that there are many ways of getting tested knowledge other than by the quantitative measurement of objective conditions, and other than by the methods employed in the physical sciences. The only question which remains is whether we should call such tested knowledge "science" or not.

This question concerns the whole future of science. The scientific movement seems to show the same tendencies shown by all other social movements in history. Every historical movement starts with some new enthusiasm, or hope, which reaches out in every direction and brings everything within the movement which may in any way serve its purpose. When the first enthusiasm is spent, the movement settles down into fixed habits which are supported by strong traditions. Gradually there grows up an orthodoxy regarding what the movement stands for, and, in order to hold their lines more securely, some leaders of the movement make the orthodoxy a very narrow one. This is evidently what occurred in the Christian movement, and we now see it being repeated in the scientific movement. Strangely enough, however, the orthodox scientists seem quite unaware that they are the victims of a hardening and a narrowing tradition. It is possible, of course, that the narrow interpretation of the scientific field for which they stand may prevail; that the scientists of the future will limit science strictly to the field of quantitative measurements. If they do so, then science can play a rôle only in the exact arts. I would not say that its rôle would be of decreasing importance, but it could have little bearing upon those deeper problems of life which concern qualities and values.

There is, however, good reason to hope that if the light of knowledge continues to increase in our world, narrow orthodoxies in both science and religion will in time disappear. Just as we have seen narrow orthodoxies in religion breaking up in our own day, so probably a not distant future will see the disappearance of tendencies to narrow orthodoxies in science. For men, if allowed to think freely, will see that the scientific spirit is the open-minded love of truth, and is quite independent of the straight-

jacket of any method. Moreover, they will see that if science does not take all verifiable knowledge for its field, then men will seek such knowledge elsewhere; for men can live in our complex world only by tested knowledge, and if science will not furnish it to them in the world of qualities and values, then some other instrument of culture will attempt to furnish it, and science will sink to second-rate importance in the guidance of life.

This is apparently exactly what some people desire; for they say that if science assumes first importance in the guidance of life it will exercise an unheard of tyranny over men. Let science confine itself to exact facts and relations, and let each individual evaluate these for himself. Let science keep out of the world of values, and let each individual, or group of individuals, decide values as it chooses. Only in this way, we are told, can we preserve freedom. But so far as science has assumed the guidance of life, it has thus far created no tyranny; and it is difficult to understand how it could do so if science identifies itself with tested knowledge. For knowledge makes truth evident, and truth makes men free. In the matter of health and disease, for example, science has not only discovered facts, but has evaluated conditions of living as regards health. No one has felt this as a tyranny, except possibly those who prefer to believe in ancient superstitions.

People have been told not to drink polluted water if they wish to avoid typhoid fever. But no one who wishes typhoid fever has been forbidden to drink polluted water. To be sure, the law, under the guidance of science, has forbidden people to give polluted water to others to drink; but this is fair, and not tyranny, because most people are guided by the values of common sense; that is, they prefer life to death and health to disease.

Now the case is exactly the same with the whole field of morals. The guidance of science in the field of conduct and of social relations could be resented as a tyranny only by those who prefer to be guided in their conduct by ancient superstitions and by unenlightened impulses and emotions. For tested knowledge, even when it concerns conduct values, places no external constraint upon the will; it only enlightens it. Nor is it true that science, if accepted as a guide of life, would stunt the growth of art, morals, politics and religion. On the contrary, when these are provided a scientific base through a critical analysis of human experience in these lines, we have good reason for believing that such scientific knowledge will aid greatly in the rational development of these phases of culture. Thus, for example, a science of religion will aid greatly in the rational development of religion. Such a science, by providing a knowledge basis for the development of religion, would in time come to be regarded as an indispensable part of religion, while at the same time it would remain a part of science. Thus the tree of knowledge might come in time to furnish nourishment to all the branches of culture which spring from its trunk. We can not agree, therefore, with Ayres that by trying to make our beliefs scientific we will make them absurd and powerless. Rather belief is too often powerless today because it is not in accord with tested knowledge.

Another historical parallel may be suggested here. Just as the Christian movement developed its narrow dogmatisms before it had reached its perfection, so the scientific movement shows similar tendencies. For, of course, our science is still very immature, and narrow views on the part of scientific men are often due to traditionalism and resistance to the process of growth. Hitherto our science has been mainly physical

science and there has been unwillingness on the part of the workers in the physical sciences to recognize the social sciences. This has led to the desire on the part of some workers in the social field to use only physical science methods and thus assert their right to be called "scientists." And such "scientists," as Bernard Shaw has said, often "actually regarded the banishment of mind from the universe as a glorious enlightenment and emancipation." Thus science ceased to be an all-sided movement toward knowledge of reality, and tended to become a narrow specialism linked with the machine and with the mechanical view of things.

Thus has come about largely the present plight of science and its present needless conflicts with other phases of culture. Science can escape from its present plight and from these conflicts only by becoming an open-minded movement towards knowledge of all reality and welcoming all methods which will assure such knowledge. But inasmuch as the most important part of reality for human beings is the human world, it is evident that if science thus broadens its scope, the physical sciences will fall to a place of secondary importance. Physical science can never be the guide of life, because it leaves culture largely out of account, and all the most important values of the human world are wrapped up in culture, yes, even in the non-material aspects of culture. A social science even which employs only the methods of physical science can not guide us, because it will miss the non-material aspects of culture and end in negations.

It is, of course, impossible to say whether or not the scientific movement will emancipate itself from the narrow dogmatisms which now threaten it. But if history involves a learning process which gradually corrects mistakes, this would seem probable. Then we could expect a development of the social sciences, largely in terms of history rather than in terms of mathematics and quantitative measurement. The sciences of culture rather than of physical nature would take the lead and have preeminence. Not only would each aspect of material culture have its supporting science, but also each aspect of non-material culture. Thus there would be pure sciences of government, of religion, of morals and even of fine art and of education, and supporting all would be sciences of human relations, of human group life and of culture itself. These studies would be recognized as having the same scientific validity as the sciences of physical nature.

It may seem to some that we have already reached this stage, or, at least, that it is immediately in the future. We may, of course, hope that this is true; but the strong movement in the scientific world to limit science to the external and the quantitative, as well as the strong movement in art, in politics, in morals and in religion to deny any dependency upon science, should warn us that the social sciences are still far from established. Only one of the non-material phases of culture definitely looks to science for guidance, and that is education, and it has not done so until recently.

Yet the great need of our present civilization is to develop as quickly as possible the non-material, or spiritual, phases of culture, especially government and law, education, morality and religion. The only possible way to develop these phases of culture is to accumulate and diffuse as much tested knowledge concerning them as possible. Naturally such knowledge will concern, among other things, the social function of each of these great phases of culture, and will seek to show how each of their historical forms functions in given social circumstances.

The opponent of science having anything to do with the practical problems of our world will probably at this point hold up his hands with holy horror, and

exclaim: "What! science indicate the relative social values in democracy and autocracy, sovietism and Fascism, hedonism and intuitionism, Confucianism and Buddhism, Mohammedanism and Christianity! Why, that would make science a partisan affair, and win for science only the enmity of the partisans of these systems." The reply is that science can not attain to a true nonpartisanship by remaining aloof from all questions which have partisans. If it did, it would remain aloof from all vital social questions, because it is a constant characteristic of vital questions that they have partisans. If science is going to remain aloof from all questions of politics, of morals and religion, then it can not function as a guide in life, to say nothing of being helpful in the development of these phases of our culture. Even such a general science as sociology will be a useless and "dead" science if it can contribute nothing to the solution of the political, moral and religious problems of human society. If Fascism and sovietism, democracy and autocracy, can not be socially evaluated upon the basis of established social knowledge, how will these problems of governmental forms be solved? It is as cowardly for the social scientist to refuse to deal with such vital questions of human welfare with the best scientific methods available as it would be for the medical or biological scientist to refuse to deal with a pestilence.

If tested knowledge is to benefit man, and if science may be identified with tested knowledge, then the great field for science in the future will be human relations. The tasks of physical science are, of course, far from completion, and the urgent needs of men in the way of food, power and physical health will probably put large demands on the physical sciences in the near future. Still the demands of social life with its increasing complexities and difficulties are even more urgent. One can not visit Europe and witness its overpopulation, the poverty and ignorance of its masses, its international and interracial hatreds and antagonisms, without realizing that if scientific knowledge can not help in the solution of these problems, the outlook is indeed dark. And I am forced to add that I could discover little or no evidence in most of the countries of Europe of the leadership of the social sciences in the solution of these problems. Science is still far from a dominating element in the life of most of these peoples. When we turn to the United States we find the situation changed, but not essentially different. We have more completely absorbed the results of the physical sciences, and created a machine civilization. But the social ignorance, the poverty, the lawlessness, intolerance and antagonism of our masses and classes persist, and become all the more dangerous because we have a machine civilization. The very advance of physical science, as Professor Soddy declares, has become a menace to our civilization if our present low social standards persist. We must have more social intelligence, more tested social knowledge and more agreement regarding social problems if our civilization is going to have even a chance of developing in a satisfactory way.

It is pathetic under such circumstances to find the leaders in the human sciences just at present apparently hopelessly divided among themselves. There are a full half dozen different kinds of psychology to-day each claiming scientific standing, and each hostile to all the other kinds; and the same condition exists in sociology. Our scientific world to-day is as badly divided as our religious, political and social. But it could hardly be otherwise; for these divisions are but indications that the method of development in our human world is the trial and error method. These divisions do not indicate the failure or the "bankruptcy" of science, as its critics so often

proclaim; they may rather be signs of growth. In part the divisions are due to one-sidedness in viewing reality, to the fact that each faction in science, quite like each sect in the religious world, sees but a part of the truth; but even more are these divisions due to the different methods and assumptions which different students of human behavior employ. Scientists in general seem surprisingly ignorant of the fact that science usually develops through trial and error. Especially do the advocates of the latest method or the latest theory in some science seem painfully ignorant of this fact; for they advocate these with all the fervor of converts to a new religion. They are certain that they are right, whereas most of us only see reason to lament that the scientific movement is made the victim of fads and fashions. But if our European mind is too dogmatic to rise above these fads of the hour to a true synthesis, if we are unable to see reality and see it whole, we may be sure not only that the scepter of knowledge will pass from us, but that some other race than ours will in time learn from our mistakes.

The great development of science in the future must be, therefore, in the humanistic direction. This trend is in evidence even in the physical sciences. The human sciences themselves will more and more come to center their attention upon the distinctively human, as the basis for man's further progress and development. Culture, in all its aspects, as we have already indicated, will become the center of scientific attention, and the subject-matter of a group of sciences, the sciences of culture, which will repudiate the method of the physical sciences, the method of weighing and measuring, as adequate for their purposes. Among the phases of culture, the non-material, or "spiritual," are the most distinctively human; therefore, they will receive the special attention of humanistic science, and the group of social sciences concerned with these non-material phases of culture will be held to be most important to humanity.

Now in these non-material phases of culture and in human relations generally the great need is a set of standards which will enable us to judge and control conduct to human social advantage. The sciences of the non-material phases of culture will, therefore, become the basis of a set of social sciences concerned with standardization. The work of sciences of standardization in the physical field, or more strictly in the field of material culture, is already far advanced. But as we have seen, there are still many who deny that we can have sciences of standards in such fields of human conduct as government, morals and religion; and that if we did have them, we would have an intolerable tyranny. It is impossible, however, to see how mankind can ultimately avoid the determination of standards upon the basis of tested knowledge in these fields. We doubtless should leave a large freedom to the individual. But this principle does not prevent the scientific determination of standards. In at least two of the non-material phases of culture the scientific determination of standards is already far advanced. I refer to education and social work. In both these fields the testing of experience, the sifting of facts and generalizations from these have led to the establishment of many helpful standards, even though we may concede that the work is as yet only begun. In charitable or philanthropic work, which is one of the most delicate and difficult of all human relations, the same procedure has resulted in well-established scientific standards. Nobody, it may be remarked, has found any tyranny in establishing standards in these lines of conduct except the few who wish to act upon impulse, or old habits.

In a word, if science becomes once thoroughly humanistic, the whole field of relative standards, values and ideals in human relations will become objects of scientific determination. The social

sciences will expand in their normative and applied aspects. Why any one even now should dread this development is hard to see. If social standards, values and ideals are not based upon tested knowledge, they will be based upon things quite untrustworthy. If on the other hand humanity can secure standards based upon tested knowledge in government, in morals, in religion and in education, and can secure the general acceptance of these through education, then progress in civilization will enter upon a new phase, the telic phase which Lester F. Ward predicted. And there is good reason to believe that even the most perplexing problems of our civilization would soon be on the way to solution. Every phase of culture, non-material as well as material, would soon be headed toward the best development for the weal of man.

Whether our age or our race will or will not carry through this broadening of the field of science which we have described it is impossible to predict. But it would seem certain that if history involves an accumulation of experience, such a broadening of what is generally recognized as tested knowledge is certain to take place. Whether it will be called science or not, is, of course, a matter of indifference. The important thing is that science in the name of its purity or orthodoxy do not put a ban upon the accumulation of such tested knowledge. Ample and accurate information, a great financier has said, is the foundation of success in the business world. We have every reason to believe that it is the foundation of success for nations and civilizations as well as for individuals. If science is unwilling to have the ample and accurate information necessary for successful human living sought, accumulated and diffused under its name, then it will have to be done under some other name.

If, on the other hand, science identifies itself with the whole field of tested knowledge, then its function with reference to other phases of culture will become clear. The conflicts of science with these other phases will disappear. I have ventured to say elsewhere that between a humanistic science and a humanitarian religion there can be no conflict. Certainly there could be no serious conflict. For between the tested knowledge regarding human welfare presented by such science and a religion which finds its expression in the service of mankind a natural and inevitable interdependence would arise. So, too, with a humanitarian ethics and a humanistic philosophy. A bridge of thoughts and values would grow up easily and naturally between science, morals, philosophy and religion. Science, both as a knowledge of facts and a knowledge of practical values, would point clearly to standards of rational social conduct. But beyond the tested knowledge of facts and values of science would lie the ultimate problems of knowledge and of reality. This, I take it, would be the field of philosophy; and a philosophy which built itself upon total tested and verifiable human experience would be strong, not weak. It would be another bridge between science and religion. To religion then would belong our ultimate values. It would be our valuation of our universe, or as Caird said, "the summed-up meaning and purport of our whole consciousness of things"; and if based upon tested and verifiable human experience, it could naturally have but little conflict with a science similarly based. The conflicts which we now find so commonly in the minds of individuals between their scientific knowledge, their ethical ideals, their philosophical beliefs and their religious faith would disappear; for there would be no arbitrary separations made between these; and they would be seen to form a natural series, which when its parts are logically interconnected, forms also a harmonious whole. Thus science and religion would become one in spirit and in aim.

THE SPLEEN

By Dr. WILLIAM DeP. INLOW

> **If the spleen swells, it is painful, and besides, it creates profuse laughter; but it is asserted, that the cutting of it out, cures that immoderate passion.**
>
> —*Serenus Sammonious*

The spleen is an organ of mystery. To ancient and modern alike he has been an object of the most active curiosity. The hypotheses which have been indulged on his nature are beyond measure numerous and visionary. He has been considered "the seat of the soul; the organ of dreaming, of melancholy and of laughter, of sleep and the venereal appetite"; a viscus that secretes the mucilaginous fluids of the joints; a bedfellow who cuddles the stomach and keeps it warm; or indeed, a mere stuffing to fill a hollow or vacuum. He has been thought about by philosopher and poet, physician and scientist, yet to-day he remains largely unknown.

The spleen is a sleek, glistening, contractile body hidden modestly in the upper left abdomen under the margin of the ribs, snuggled in between stomach and kidney, colon and diaphragm. He weighs about six ounces. His shape is described variously by the anatomists as ovoid, ellipsoid, tetrahedral. He looks like a pebble in birds, like a Y in marsupials and monotremes. In many animals he has strange notches and fissures, and in the porbeagle shark he is hundred lobed. He occurs only in vertebrates.

Who has not been served from the stuffed belly of a fowl a mottled purple pellet the size of the heart, the luster lost in the cooking? It was the spleen. In man at birth his color is a *beau rouge;* this tint accentuates itself little by little in the first years, then pales in old age till it becomes a *gris sale.* Cherry red in youth, bluish red in middle age, the milt in the senile appears dark blue like the blood shining through the veins on the back of the hand.

Of what use is this structure? He has an artery leading to him so big for such a small organ; he does not stay quiet, but contracts rhythmically; he does not remain one size, but swells at the height of digestion; his blood flows back through the enormous liver; he is made up of lymphoid tissue somewhat like the lymph glands; he has been cut out with impunity. Shall we believe the philosophers, the scientists or the poets? Indeed, it seems that we can cull as little knowledge from one as from another. We shall have to dig deep for a few brilliants, and thumb many manuscripts of no interest; it will be only human if we become beguiled by the excursions of fancy. Instead of splenic facts we find only phantasies to clutter the highways of sober thinking. We shall listen first to the voice of history, then to that of the experimentalists and lastly to that of the poets.

I

> **An idle member and good for nothing.**
>
> —*Russus Ephesius*

The opinion that the spleen is unnecessary and of no use to the individual has prevailed with an uninterrupted succession in the world in all ages from the oldest antiquity. In Persia so many centuries ago as the reign of Abauserus it was a custom to eviscerate the milt from horses that were kept to carry the king's dispatches, in order to give them more agility and swifter feet. The great Aristotle thought the spleen to be no more than a spurious liver planted in the left side to answer that in the right, that, a balance thus preserved, neither side

might preponderate. He affirmed that the spleen is necessary by accident to those that have him, even as the excrements of the belly and the bladder. Plato calls the spleen a collection or heap of impurities, purgations and off-scourings.

Great numbers of the ancients, being persuaded that the spleen was not only superfluous and impertinent but likewise detrimental and mischievous, thought it very desirable that their patients be freed from such a noxious companion, and therefore applied their industry to find out effectual ways and means to extirpate and destroy him; and this they attempted by internal medicines and external applications and by manual operations. Among the medicines especially prescribed was scolopendria or asplenium. The discovery of this drug is related by Vitruvius, who, speaking of a certain river between Gnossos and Cortyna in Crete, says that the cattle that feed near Gnossos have a large spleen, but that in those that feed on the other side near Cortyna the organ is scarcely discernible. Physicians inquired into this matter and found in these places an herb, which when eaten by the cattle greatly diminished their spleens; then gathering this plant they prescribed it and called it asplenium, that is, consumer of the spleen. The method of operative removal employed consisted in raising the skin incumbent on the spleen by means of a hook and then burning this through by an oblong red-hot iron.

William Stukeley in the beginning of the eighteenth century not only considered the spleen a reservoir for blood, a sponge as it were to soak up the excess and later give it out as needed during digestion, but also advanced the opinion that this organ by his proximity, great vascularity and timely congestion furnishes heat to the stomach. He maintained that nature proclaimed the great eminence of the spleen by his situation on the left side where digestion is chiefly performed, closing the stomach up like the door of a furnace that it might have an equable warmth all around. He further adduced as proof of this assumption the notorious and terrible effects produced by eating ice in hot countries!

Patrick Black, of the hospital of St. Bartholomew, in a fanciful skit on the spleen's marriage wonders if it is not a matter of considerable importance that the milt empties his blood back through the liver. He emphasizes this by an illustration.

> Think of our court of Aldermen sitting down to dinner at the Mansion House. They begin with turtle and iced punch; this is followed by a dinner of six courses, with wines "still" and "sparkling," every five minutes, for the space of about two hours; the whole is concluded with copious libations of port wine. Is it of no consequence whether these gentlemen take their spleens with them to the banquet or not? In your own case, physicians in high practice and professors of physiology, would you entrust your portal system to take so much of this rich material direct to your Liver, before it was well watered by your Spleens? I trow not.

Finally, must we not crave leave to do justice to an eminent divine and to Isidore, who do more than assert the usefulness of the spleen, for they plead for the necessity of him to prevent a vacuum; for that they say, must have been the sad consequence had not that place in the left side been filled up by the spleen. And then how dreadful a condition had the world been in!

II

The spleen has been excised in animals thousands of times in order to try to determine his significance in the animal economy. Alas, the disturbances occasioned by his absence have been slight. Modern splenectomists have been but little more successful than their predecessors.

There has been no want of high ability, no absence of ripe knowledge, but withal no guiding idea. A few philosophers have met together, and made the following arrangements. One is to bring his lens or microscope; the chemist his bottles and test-tubes; the pure anatomist his injecting pipes and fine instruments; may I add to these the vivisector with his rabbits from Leadenhall Market? They meet and confer. "It will be hard indeed," they say, "if we don't strike out something amongst us." Yet, with all this fine ability, these great resources, and high promise, they have to bear this hardship—they stumble upon nothing; their work, though varied and ingenious, has been infructuous; they conclusively establish many negations, and they record them all in a report, which, though deemed a model of philosophic inquiry, is one, nevertheless, in which they have only to inform the world where they have not found the object of their research.

Malphigi, the eminent Italian anatomist, was the first to endeavor experimentally to solve the riddle of the spleen. Assisted by two ingenious friends he opened the side of a young dog and bound the blood vessels at the entrance of the spleen with a strict ligature. The dog not only survived the operation, but performed with alacrity his natural functions without any mark of impaired health. After a space of time Malphigi opened the dog again and found the organ shriveled and shrunk to the minutest size, looking like a dried-up hull. He did not find the use of the spleen; yet, had he reflected, he might easily have found out, as wittily remarks a sage commentator, that this bowel was of no use at all!

Among the earlier splenectomists was the later renowned French surgeon, Dupuytren, at that time a rising professor of the École Pratique. "We may suppose some of his youthful companions thus addressing—'Dupuytren, a quoi sert la rate?' He would shrug his shoulders, *more Gallico*, the meaning of which we all know, and would add, 'Cut it out and watch the result.'" This they did and repeated it even to the fortieth time. Those animals that recovered began to show, about the third week, some symptoms of returning appetite which was designated as a state of "remarkable voracity." This, however, was all the philosophy cut out of those forty dogs.

Henry Gray, the well-known English anatomist, worked assiduously on the spleen. His dissertation won the Sir Astley Cooper prize in 1854. He dissected great numbers of all sorts of beings from eels to lions; he experimented on London cab horses and on donkeys. It is chiefly the present novelty of his experimental animals that seems remarkable.

Among the moderns it is probably our own W. J. Mayo who has removed more human spleens than any one else. To him the spleen is a sieve, a strainer which removes from the blood bacteria and protozoa, poisonous products and worn-out blood corpuscles. Indeed, the study of disease in the human has given more insight into the problem of the spleen than anything else.

Even among the earlier physiologists deducing their results from their splenectomies we find at times ideas almost as fantastic as those we have just gleaned from the philosophers. Thus certain enterprising experimenters have observed after removal of the spleen: diminished fecundity, frequent choking and vomiting after a hearty meal, increased liability to watery effusion into the serous cavities and favoring of the assimilation of fat!

But what is it that the modern scientists know and believe concerning the spleen? He gives rise to red corpuscles during fetal life and shortly after birth, and in some animals throughout life. He is supposed to be an organ for the destruction of red corpuscles. He takes part in some way in the processes of immunity. The physician sees him enlarged and affected secondarily in many

diseases, while his primary and peculiar diseases are rare. The surgeon removes him occasionally for rupture from injury, and as a curative procedure in some of his primary affections. All are looking forward to an understanding of his full significance.

III

Nature has formed me of satiric mould,
And spleen too petulant to be controlled.
—*Persius*

Who indeed cares about the spleen, or would take the trouble to listen to anything that might be said on the subject? Has he not been cut out of the body hundreds of times after the most approved method of settling physiological questions? Has he not as frequently been proved to be utterly useless or superfluous? Why then bring his dead carcass out of that tomb of physiological oblivion to which he has been so long and so justly consigned? Let him live, if indeed he be allowed to live, to please the fancy of the poets, for whom alone he seems to have been created. Surely they will gladly take him over from the willing hands of the philosophers, and be merry over his true function which they alone have had the good fortune to discover.

We shall listen first to a poetess, the Countess of Winchilsea, writing a Pindaric ode over two centuries ago.

So Protean as his form, so infinite seem the moods at the spleen's beckoning. The surging of surfs, the happy gurgling of freshets lie hidden in the calm dead of his waters. He is father of the wraths of peasants, the passions of courtesans, the melancholic broodings of lovers disconsolate. Monks pray, friends listen in groves to low-toned contumely, battles lose themselves at his mandate. Who does not know of the monstrous vision of Brutus before Philippi; who has not at midnight seen pointed fires and specters dance? They say it is the spleen that gives the lure of the cup, the inanity of garrulity, the excuse of foppishness. Untamed from drinks of the Orient, unsoothed by the lull of indolent music, it is ever his wont to break forth in peals of acidulous laughter.

When the coquette, whom every fool admires,
Would in variety be fair,
And changing hastily the scene
From light, impertinent and vain,
Assumes a soft, a melancholy air:
And of her eyes rebates the wand'ring fires,
The careless posture and the head reclin'd,
The thoughtful and composed face,
Proclaiming the withdrawn, the absent mind,
Allows the fop more liberty to gaze,
Who gently for the tender cause enquires,
The cause indeed is a defect in sense,
Yet is the spleen alleg'd, and still the dull
pretence.

The sullen husband feigns his spleen when he spends his ill humor with his wife. So it is with all gross abuses. The imperious wife herself is not immune. Overheated passions rise in crowds to the attractive brain, overcast and showering eyes play upon the spouse's softened heart; he yields the disputed point. Mistaken votaries to the powers divine restrained from speech and banished to deserts or reclused in cells but obey the spleen and worship at his shrine. Thus religion suffers from the dire effects of the more powerful charms; religion that should enlighten all here below is veiled in darkness and perplexed with anxious doubts, vexed with endless scruples and some restraint implied from each perverted text. Touch not, taste not what is freely given is but the niggard voice of the spleen disgracing bounteous heaven.

The fool to imitate the wits
Complains of thy pretended fits,
And dullness born with him would lay
Upon thy accidental sway;
Because sometimes thou do'st presume
Into the ablest heads to come.

No sweets till the reign of the spleen could shock the sense or bring to the face a flushed unhandsome color. Now the jonquil overcomes the feeble brain, and we faint till some offensive scent placates

the powers of the spleen and we resign pleasure for short and nauseous ease. Through the spleen's black jaundice which overtakes us we see all objects as dark and terrible as the mysterious organ himself. We use all means to free ourselves from his spell, all arts, all remedies—we quaff infusion of the Indian leaf, bruise the parched eastern berry—all is of no avail. We seek to chase this strange malady with the gentle strains of many melodies; thus do we hope to divert the murkiness of his stream of icteric influence. We inspire the flute and touch the string in vain; no help is had from harmony—music if too sweetly sad but soothes him, and if too light but turns him gaily mad.

> The son of Bacchus pleads thy power,
> As to the glass he still repairs;
> Pretends but to remove thy cares,
> Snatch from thy shades one gay and smiling hour,
> And drown thy kingdom in a purple shower.

Poesy thus ascribes to this organ as many and diverse functions as do philosophy and science; furthermore these functions are just as contradictory, or more so. While the scientist sees the spleen in the double capacity of both a creator and a destroyer of red corpuscles, a being like the mythic Saturn, who devoured his own children, the poet sees him both as the organ of mirth and laughter and of sadness and melancholy. Probably the primary interpretation was that of mirth.

> Such fantastic tricks
> As make the angels weep; who, with our spleens,
> Would all themselves laugh mortal.
> —*Shakespeare,* "Measure for Measure"

The interpretation of melancholy is associated with the ancient conception of the spleen as the seat of black bile. It is illustrated in the modern German word for hypochondriasis, *Milzsucht.*

> *Tempelherr:* Wozu?
> Ich habe Fleisch wohl lange nicht gegessen;
> Allein was tut's? Die Datteln sind ja reif.
>
> *Klosterbruder:*
> Nehm' sich der Herr in Acht mit dieser Frucht.
> Zu viel genossen taugt sie nicht, verstopft
> Die Milz: macht melancholisches Geblüt.
> —*Lessing,* "Nathan der Weise"

Yet another interpretation used by the poets is that of anger, probably an innovation on the original meaning.

> and at the last he sware
> That he would send a hundred thousand men,
> And bring her in a whirlwind; then he chewed
> The thrice turned cud of wroth, and cook'd his spleen,
> Communing with his captains of the war.
> —*Tennyson,* "Princess"

This organ excised for the swiftness of horses by Persians, dwindled to nothingness in kine by the feeding on pastures of Cretans, heavy with foul liquors drawn off the livers of Greeks and of Romans, made famous by the Italian Malphigi, is thus seen to be a creature of caprice and of many moods, created apparently to subserve the fancy of the poets. For to the modern physician even as to the great Galen of the past the spleen remains *mysterii pleni organon.*

THE IMPORTANCE OF NUTRITION IN CHILD HYGIENE

By Dr. VICTOR E. LEVINE

DEPARTMENT OF BIOLOGICAL CHEMISTRY AND NUTRITION, SCHOOL OF MEDICINE, CREIGHTON UNIVERSITY

NUTRITION has come to be looked upon in the last few years as a very important factor in the life of the individual. The spirited public-health worker realizes the importance of diet for maintaining health, and the progressive physician is now effectively employing diet as a therapeutic measure.

In a great nation it is very desirable for its citizens to use all the known means of science to keep physically fit. It may be surprising to many of us to realize the extent of ill health in our own country. The report of 1918 of the Department of Labor, Children's Bureau, Washington, D. C., presents figures that should awaken even the most indifferent citizen. There were in 1918 approximately twenty-two million school children. At least 1 per cent., or 200,000, ranked among the mental defectives. At least 1 per cent., or 200,000, were handicapped by organic heart disease. At least 5 per cent., or one million, were on the verge of having tuberculosis. At least 25 per cent., or five million, had defective vision. From 15 to 25 per cent., or three to five million, had diseased tonsils and other glandular troubles. From 10 to 20 per cent., or eleven to sixteen million, had defective teeth. At least 20 per cent., or four million, were suffering directly from malnutrition. At present one third of Chicago school children have some nervous disorder, and two thirds of New York school children are physically defective.

A large percentage of growing children are underweight for their height. Judged by standard height-weight tables, from 15 to 40 per cent., and even as high as 60 per cent., of school children have been found to be undernourished. In a study of 506 children selected as the best specimens of health that could be found among school children, it was found that one fifth of them were underweight according to the standards most frequently used in school work in the United States. Twenty per cent. of these children were more than 10 per cent. underweight according to Wood's standard height-weight-age tables; 13 per cent. were more than 10 per cent. underweight according to Dryer's standard stem length and chest circumference tables.

Undernourishment and malnutrition have been found to be prevalent among the children of the well-to-do as well as of the poor. To remedy this condition requires individual diagnosis of the cause in each instance, and success often depends upon the cooperation of the parent, the teacher, the physician and the child.

Over a billion dollars is spent each year by our nation for the education of the pupils in the schools, but only twelve to fifteen million dollars is expended for school health work. Only sixty-five cents per child per year is spent on health, that is less than 1.5 per cent. of the total school fund. No wonder that 15 to 20 per cent. of non-promotion, retardation in studies and elimination of children from school is the result of ill health and the neglect of remediable defects. No wonder that

approximately two hundred thousand children die each year, 130,000 of these coming from the public schools.

The physical imperfections in the children of our land reflect the physical condition of our adult population. Our first national health inventory came through the World War, when about five million men between twenty-one and thirty-one years of age were examined as to their physical fitness for military duty. The records of the War Department proved most convincingly that a large per cent.—about 30 per cent.—of our young men could not serve their country by reason of physical unfitness. At this rate we may state that about twenty-five million young people in the United States are below par and in need of more or less immediate medical attention.

Some authorities claim that out of the present population of 110,000,000, only 19,500,000 are in full vigor, 37,500,000 are in fair health, while 45,000,000, or about one half of the population, are more or less physically imperfect. All the time in the United States there are three million people seriously ill, and every year we have about one and one half million deaths, by far the greatest number of which are needless and premature. For every death there is an average sickness of two years, or for each death per year there are two persons sick throughout the year.

In the past several decades there has been a steady gain in vitality in the younger age groups. This gain, unfortunately, has served to mask a loss in vitality at the older age periods. This latter phenomenon, a rising mortality in elderly life, is not exhibited in the mortality statistics of European countries. It is almost exclusively peculiar to the United States. The cause of the increase in morbidity and mortality in the later decades of life is due to the increase in the so-called wear-and-tear diseases, the degenerative diseases, the harvest reaped from unhygienic habit disorders. About half a million people die each year from degenerative diseases, heart disease, arteriosclerosis, hypertension, cerebral hemorrhage, diseases of the kidney, diabetes and diseases of the liver. The only group of diseases which can compare with this frightful loss is the respiratory group, which includes pulmonary tuberculosis, pneumonia, influenza and bronchitis. About 65,000 people die annually in this country as a result of degenerative diseases before they reach the age of fifty, and about 30,000 before they reach forty.

Health, our greatest national resource, we squander recklessly. The American people are indifferent to personal and community health problems. They have not yet taken up the conservation of health and the prevention of disease with the same enthusiasm and wholeheartedness with which they carry on their industrial and commercial enterprises. It is strange but true that year by year the human being tends towards omnipotence over the forces of nature, remaining an irrational primitive only in the lack of command over himself. We are occupied largely in treating symptoms, not in fighting disease; in dealing with the results of ill health, not with the keeping of good health. During the World War, a period that consumed less than five years, over seven million persons were killed. Those of us who read this figure with grief and sorrow in our hearts fail to realize that the horrors of peace exceed those of war. Not less than seventeen million lives throughout the world are lost each year as a result of preventable disease.

The general lack of good health, which we have briefly touched upon, is revealed, moreover, in a highly successful and prosperous country possessing an

enviable climate, and in spite of the great advances we have made in hygiene and sanitation. Wherein lies the cause of this widespread physical deterioration?

Among the factors figuring prominently in the causation of degenerative diseases are: (1) the habitual use of drugs (alcohol, tobacco, patent medicines, laxatives, headache powders); (2) venereal diseases; (3) deficient elimination; (4) a negative mental attitude—chronic fear, worry, mental unrest, anxiety, inferiority complexes, fits of temper; (5) minor chronic infections, which are usually neglected; (6) remoteness from nature—lack of sunshine, lack of fresh air, indoor life and lack of exercise; (7) strenuous living—with its many hours of fatiguing concentration and too few hours of relaxation, and (8) nutritional errors.

McCollum, of the Johns Hopkins University, has spent many years as an investigator in the field of nutrition. As a result of intensive research this brilliant man has enriched his chosen field with many fundamental facts and underlying principles. He has been, indeed, very instrumental in raising nutrition to the dignity of a science. His work does not end with the laboratory. He has gone one step farther. Through his books, his public lectures, his students, his contacts with groups organized for social, civic or hygienic improvement, he has finally succeeded in democratizing and socializing this knowledge of nutrition. Listen to him for a moment for the explanation of the present state of lack of physical well-being in our country:

> If one examines the writings of those of to-day who are most active in studying the health problem of children and in arousing the nation to activity in their behalf, one finds various causes assigned for existing conditions. All would agree that we must attribute our physical deterioration to subjection of the human race to new and unfavorable conditions, but differences of opinion exist as to the nature and relative importance of these. The sedentary life within houses instead of out-of-doors, the wearing of clothing instead of exposing the skin to the weather with its changing conditions; the eating of soft, cooked food instead of raw, coarse food; the debilitating effects of certain climates, the preservation of weaklings through improved hygiene and care, the artificial feeding of infants instead of nursing, the burden of responsibilities of civilized life, both mental and moral, and the failure to care for the hygiene of the mouth are among the causes most important. Doubtless each of these plays its part in contributing to place civilized man in many parts of the world in his present unenviable position with respect to health. It can now, however, be asserted with assurance that the chief factor responsible for human deterioration in recent times is not included in the above list. *The chief factor lies in the unwise choice of food.*

We have spent a good deal of money and effort in the breeding of stock. We should pay much greater attention to the raising of the human being. For failing to do so Rose Trumbell rightly rebukes us in her powerful poem:

THE BREED OF MEN

You talk of your breed of cattle
And plan for a higher strain,
You double the food of the pasture,
You heap up the measure of grain;
You draw on the wits of the nation
To better the barn and the pen,
But what are you doing, my brother,
To better the breed of men?

You talk of your roan-colored filly,
Your heifer so shapely and sleek,
No place shall be filled in your stanchions
By stock that's unworthy and weak.
But what of the stock of your household,
Have they wandered beyond your ken
Or what is revealed in the round-up,
That brands the daughters of men?

And what of your boy? Have you measured
His need for a growing year?
Does your mark of his sire on his features
Mean less than your brand on a steer?
Thoroughbred—that is your watchword
For stable and pasture and pen,
But what is the word for the homestead?
Answer, you breeder of men!

The great part that improper nutrition plays in the causation of disease is realized more fully when we consider the vast biologic damage faulty food can inflict upon the young as well as upon the adult. Malnutrition leads to greater susceptibility to infection. The frequent cold or sore throat, the infected sinus, the infected tonsil, the middle ear infection, bronchitis or tuberculosis is apt to strike readily the malnourished individual. The death-rate from acute respiratory disease is exceedingly high in children under five years of age, a period when malnutrition occurs frequently and with great disaster.

Malnutrition leads to disturbances in the development of bone and teeth. Poor teeth, soft chalky teeth, carious teeth, missing teeth and infected gums are indications of improper feeding. Scurvy, rickets and other diseases caused by faulty food destroy very early the integrity and health of dental structures. Mechanical brushing of the teeth is an external method for personal cleanliness and beauty. Hardness or softness of food or mastication has very little to do with keeping teeth in a healthful condition. For sound teeth and gums we need a well-balanced diet.

Malnutrition leads to symptoms referable to the gastro-intestinal tract, such as distress after eating, a feeling of fulness and pressure, abdominal pain, gastric anacidity, hypoacidity or hyperacidity, gastric or duodenal ulcer, diarrhea and constipation. It has been estimated that 50 per cent. of the American public is constipated, and that this vast army of constipated bipeds consumes annually laxatives to the amount of fifty million dollars.

Malnutrition leads to stunting in growth, to underweight or to overweight, to moderate or severe anemia, to muscular weakness and general debility, to faulty posture and to fatigue. Improper diet may bring about injury to the kidney and to the heart muscle.

Malnutrition injures the glands of internal secretion, glands which furnish the biologic urge or drive of the individual. Malnutrition produces marked changes in the nervous system anatomically and physiologically. Malnutrition spares nothing, for even the emotional and mental life of the individual may suffer. An ill-fed individual is apt to be irritable, melancholy, languid, apathetic, lacking in determination, in ambition and in the power of concentration.

We are beginning a new era in the history of the human race. Our past civilization has been built upon institutions, governments, great industries, great commercial enterprises, great highways, great cities. This type of civilization, the sun of which is now setting, holds as its goal impersonal perfection. The newer type of civilization, the sun of which is now rising, takes as its goal the perfection of the human being, who is after all the controlling force that dominates any institution or institutions. This newer aspect of civilization really leads us into humanization. It has developed for us the social sciences, sociology, economics and psychology, preventive medicine and hygiene. It has crystallized for us the ideal of social service. This newer aspect of civilization heeds the prophetic voice of the coming age and aims to correct the errors of the past.

It was Edwin Markham who was one of the first to see clearly the trends of the new spirit. In his poetic way he protests against the old order of things and makes demands for the new:

> We are all blind until we see
> That, in the human plan
> Nothing is worth the making, if
> It does not make the man;

Why build these cities glorious
If man unbuilded goes?
In vain we build the world
Unless the builder also grows.

Year by year we begin to realize more and more fully that the strength of humanity lies in the individual and that the chain can not be made stronger than its weakest link. We begin to comprehend more deeply the importance of the fact that the unit of society is the individual and that whatever brings out the best in the individual is a gain for society as a whole. Our educational ideals have changed to harmonize with this concept of social philosophy. The aim of education is no longer to make a gentleman or a lady. Its aim is not, as some would have us believe, to develop an individual capable of gaining a livelihood. Its aim is much higher. Its supreme goal is the development of the individual in all his potentialities, physical, mental and spiritual. In short, modern education holds out as its product the man or woman with an all-rounded personality, armed with health and vision and knowledge, prepared to carry on in a world full of complexities, competition and rivalries.

Happiness is an inward adjustment, but it depends to a large degree upon external factors. Among these factors we may mention health. Loss of health is the greatest obstacle to happiness and activity. It mars the personality. It cramps its possibilities. It limits its usefulness.

Health is not a gift given freely. A positive mental attitude is required to hold this priceless treasure. A knowledge of the simple laws of hygiene and sanitary living is indispensable. A conversion of this knowledge into correct life-lasting hygienic habits is absolutely necessary. As Huxley has stated, the aim of education is not knowledge but action.

Man as he reaches maturity unfortunately loses the flexibility of youth. He becomes an unyielding bundle of habits not subject to great correction or change. To attempt to modify habits of life in the average adult man or woman is almost a useless task and a thankless job. On the other hand, youth is plastic, receptive, acquisitive. The boys and girls in the care of the parent and the teacher are rough stones direct from the quarry, ready to be fashioned into beautiful living monuments.

Among other things, the parents and the teacher can lay the foundation for a sound mind in a beautiful, healthy body. They can reveal an interest, keen and enthusiastic, in personal hygiene. They can build in through the dispensation of knowledge and through their own daily practices the habits that lead to a healthful life, and they can destroy that cankering sore, malnutrition, which undermines the health of the boy and the girl, and which may prove to be the basis of much of the disease processes that rob them in later days of the good things of life, nay even of life itself!

We in this great country of ours are apt to lay great stress on some things and underemphasize others. We brag about our material prosperity and about the twenty-five million automobiles we own. You remember the story of the famous Roman lady, who boasted to her guest of her priceless jewels. When requested to show them, she immediately brought forth her two lovely children and proudly proclaimed that these were her priceless jewels. With the same pride as that shown by Cornelia, we should point to the immense wealth and treasure represented by our thirty-five million children. In the words of Phillips Brooks, "The future of the race marches forward on the feet of little children."

To the parent and to the teacher, each and every one of these millions of children speaks and says in his own way:

I am the captain of industry of the next generation, the creator of things ugly or beautiful, the saint or the criminal, the man or woman of action and energy, or the man or woman of sloth and indolence.

I hold in my hand the future of civilization. I can destroy the sweet fruits of the labors of the past, or I can plant the seed of even greater happiness than now exists.

In short, what I am to-day or what I shall be to-morrow, depends much on you.

I am the question to which you make reply.

We are living in an interesting period of transition. Life is becoming more intricate and more complex, while at the same time the hours of leisure are increasing, and the joys of life, physical, mental and spiritual, are multiplying rapidly. The school, reflecting as it should the life of the times, has also increased its activities in many directions. It has enlarged its scope, and it has even been forced to invade the field of that teaching formerly the province of the home.

In order that the child may successfully cope in later life with the ever-increasing demands upon its vitality which modern living necessitates, we have begun to incorporate into the curriculum the art and science of healthful living.

We have made much progress in preventive medicine. We have conquered many infectious diseases, like smallpox, diphtheria, measles and scarlet fever. We have almost slain the monster of infection. But a new monster even more ferocious and destructive has arisen in our midst. This new monster is represented by the degenerative diseases, the wear-and-tear diseases, the diseases due to habit disorders—heart disease, high blood-pressure, hardening of the arteries, softening of the brain, cancer, diabetes, diseases of the kidney and liver. The result of these habit disorders is appalling and should provide food for thought even to the most indifferent. Each year half a million people die prematurely in the midst of their greatest activities and their best efforts. These deaths are all preventable, if we begin in infancy and childhood to impress the plastic mind with the habits of health, which will be followed subconsciously into what now is considered the dangerous and tragic middle age and the dangerous and tragic period known as old age. If we are as highly civilized as we think we are, and as humane, scientific and wealthy as we claim to be, what excuse have we to offer for permitting millions of people to be constantly ill from preventable disease, and the lives of our fellow beings to be sacrificed to ignorance and neglect?

In view of the great price paid for the neglect of health in childhood days, no boy or girl should be subjected during the period of growth and development to undue and to unnecessary biologic strain or deprivation. No child should be allowed to suffer physical or mental retardation through malnutrition. If such condition unfortunately exists it should be removed at once, for viewed from a broad aspect it is often brought about by causes which have sociological and moral import. Improper food habits are by no means the only cause of malnutrition. Among other equally important causes are physiological defects and pathological processes, lack of home control, chronic overfatigue and improper health habits. These very causes have their roots in the base of the social, hygienic and moral status of the family, in which environment the child is placed by the force of circumstances.

The greatest problem of conservation relates not to forests or mines, but to national vitality. To conserve the latter we must begin by conserving the child.

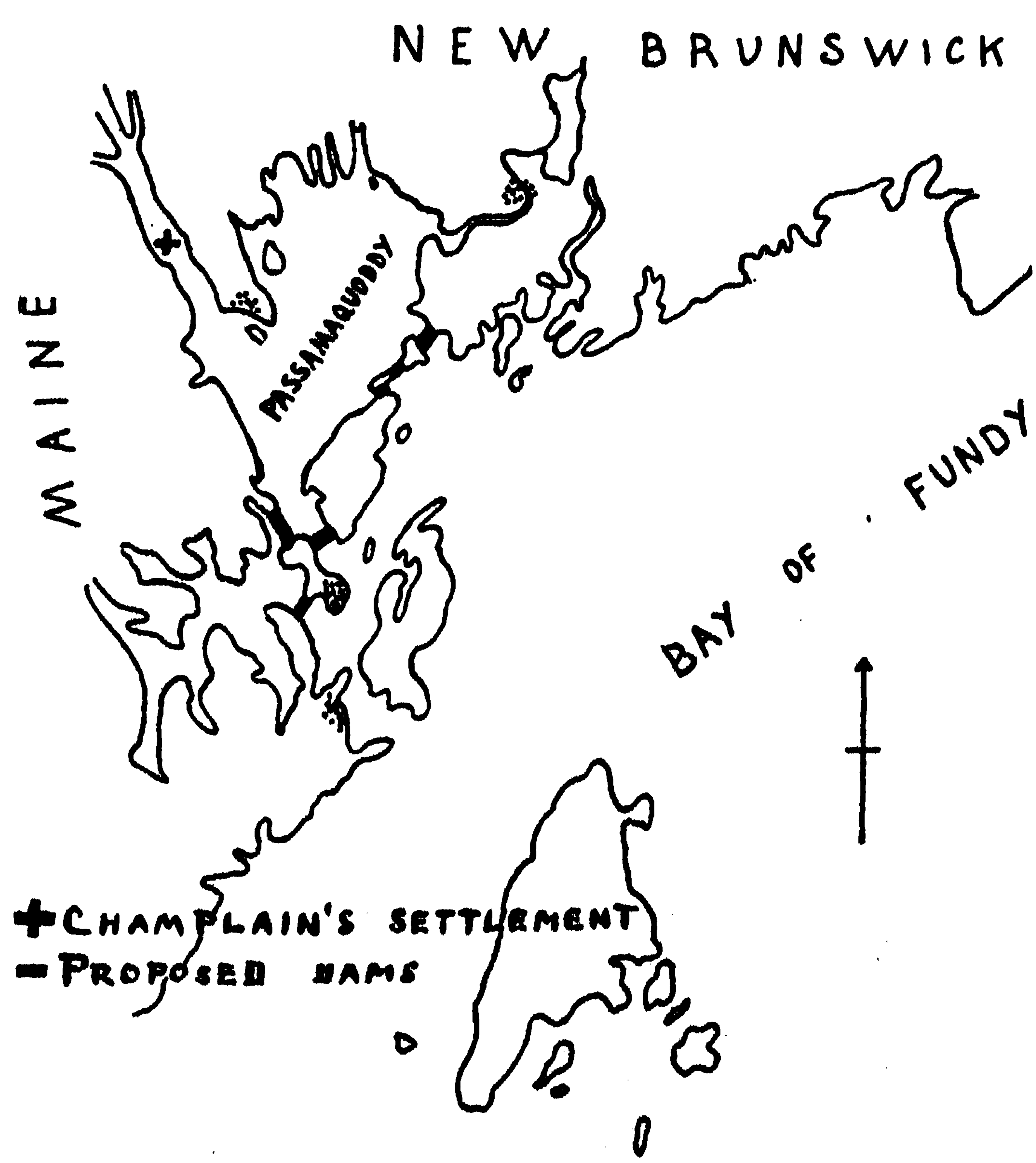
THE THREATENED SARDINE FISHERIES OF PASSAMAQUODDY BAY

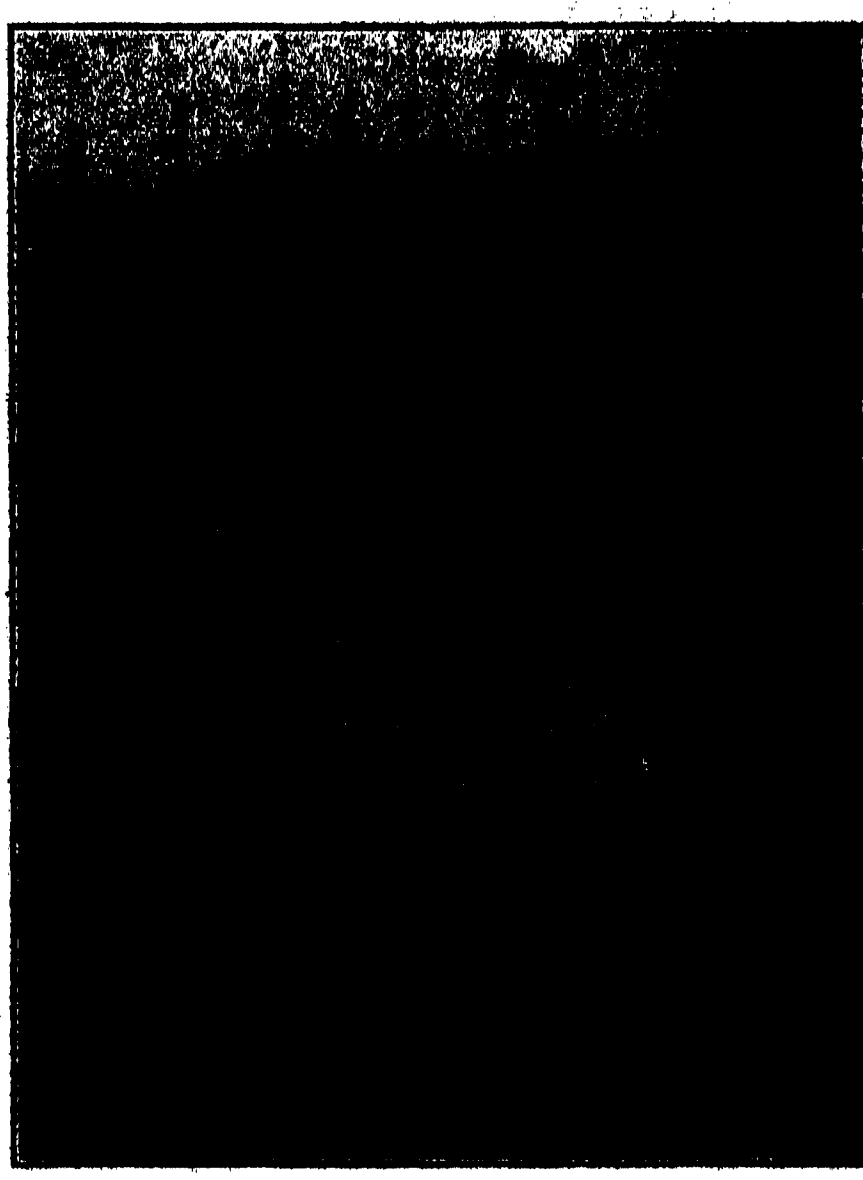
By Dr. N. J. BERRILL

DEPARTMENT OF ZOOLOGY, MCGILL UNIVERSITY

At the mouth of the Bay of Fundy, separating Canada from the United States, is a large sheltered inlet known as Passamaquoddy. It has long been of interest in that it is the scene of the first settlement north of Cape Cod, and has had a checkered history in the border disputes following the War of Independence and of 1812.

The coast in this region was first visited in 1603 by Martin Pring in the *Speedwell,* though no settlement was made; but in the following year De Monts, with Champlain as his pilot, set out with a charter from Henry IV of France to colonize and rule all American territory between the fortieth and forty-sixth degrees of latitude. He first explored the Nova Scotia coast and the Bay of Fundy, during which voyage the St. John River was visited and named, and thence proceeded into the waters of Passamaquoddy. He ascended the river that he named the St. Croix to a small island, which Champlain selected for a fortification and a settlement for the winter. The selection of an island was due to fear of savages, but it was doubtful wisdom since wood and water had to be obtained from the mainland, and before the winter had passed thirty-six men out of the seventy had died of scurvy.





FISHERMEN DIPPING SARDINE INTO SMALL BOAT, HAVING FIRST CONFINED THEM WITHIN THE SEINE NET. THE INNER LINING OF NET TO THE TRAP CAN BE SEEN IN THE BACKGROUND.

Many years later, after the War of Independence, when it was agreed that the river St. Croix should mark the international boundary, there was prolonged dispute as to which of the rivers entering Passamaquoddy Bay was the real St. Croix, and it was settled definitely only when Doucet Island in the Schoodic River was explored and De Monts' forgotten settlement discovered and excavated. For several generations now this region, with its islands, strong currents and fogs, has been the scene of a flourishing sardine industry.

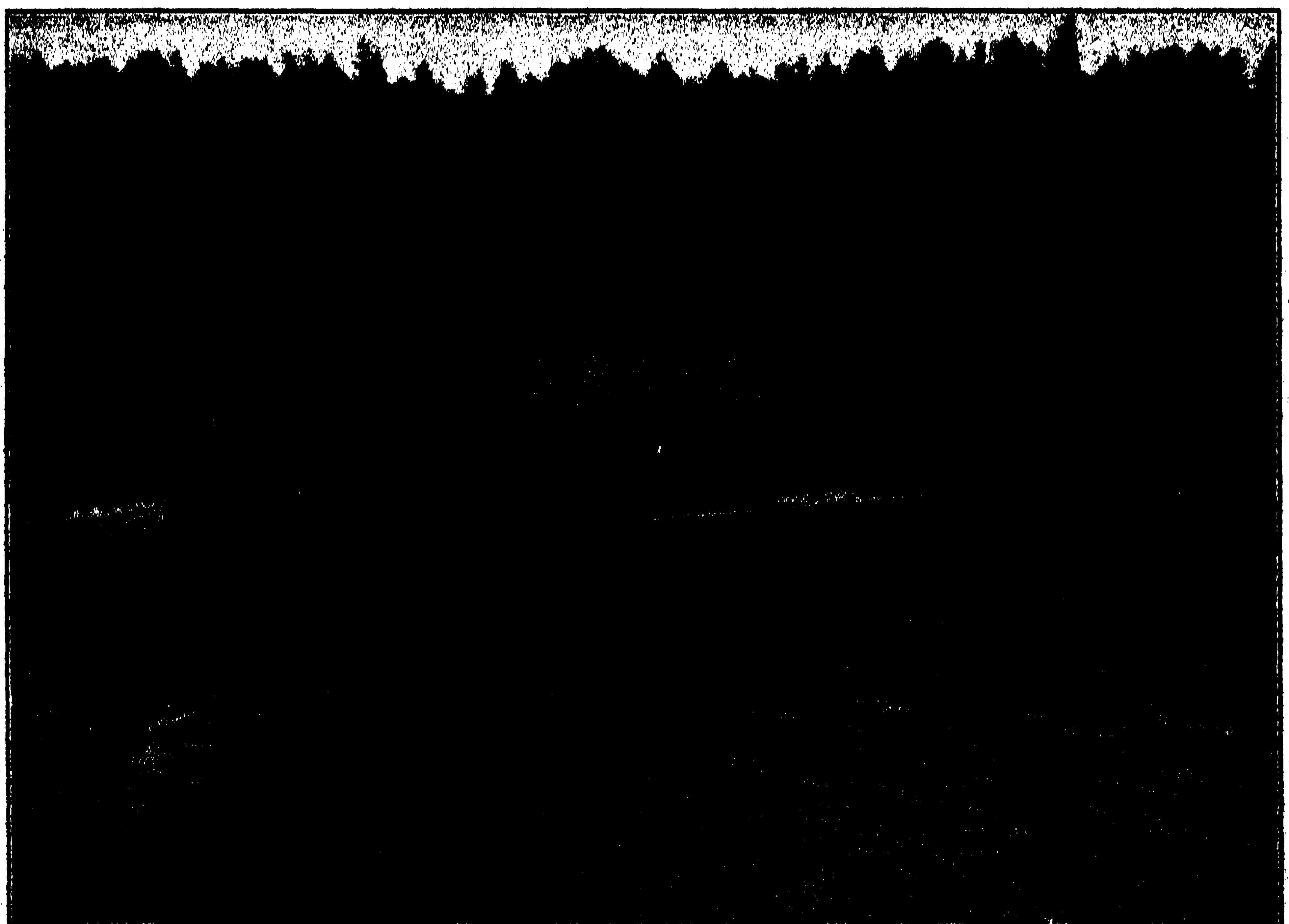
Passamaquoddy itself is an Indian name for "plenty-of-pollack," and the whole area is remarkable for the abundance of young herring or sardine, and of haddock, that are to be found in its waters. The abundance, in fact, is not confined to fishes but is true of such invertebrates as sea-urchins, sea-cucumbers, starfishes, clams and sea-squirts; and in several places along the coast factories have been established for preparing clam-chowder.

This wealth of animal life depends primarily upon a corresponding wealth of minute plant life, and this in turn depends everywhere in the sea on the presence of such salts as phosphates and nitrates. Throughout the oceans the quantity of these salts is very limited, and by the end of summer growth and multiplication of the microscopic plants come to an end through the exhaustion of the salts, and further growth does not take place until after the winter when rivers and destruction of living organisms have replenished the supply. In Passamaquoddy waters, however, conditions are unique. The bay itself is a sheet of water of about one hundred square miles, separated from the Bay of Fundy proper by a chain of islands; and since the rise and fall of the tide is about twenty-five feet, the cold deep

SARDINE BEING TRANSFERRED FROM SMALL BOAT TO THE HOLD OF THE BUYER'S VESSEL. THE SCENE IS IN THE ANGLE FORMED BY THE STAKE FENCE AND THE WALL OF THE TRAP ITSELF.

waters of the Labrador Stream, sweeping south of Nova Scotia, boil and swirl to the surface as they endeavor to force their way through the narrow channels between the islands. In so doing they bring to the sunlit surface where it can be utilized a continual supply of the salts so essential for the growth of the floating plant organisms. To these conditions, then, are due the presence of multitudinous shoals of young herring and other forms of life, and on them depend the sardine industry. This industry is divided between the two countries. The great majority of the fish are caught in Canadian waters by Canadian fishermen, but most of the canning factories are on United States territory. In fact, Eastport and Lubec, the two most northerly coast towns of Maine, depend almost entirely upon such factories.

The method of catching the small herring is based upon the habits of the fish. The shoals usually move close to and parallel with the shore-line, and move out from it only when some obstacle is reached. Traps have consequently been devised that consist of a long fence of stakes and brushwood extending at right angles to the shore and which end in the open mouth of a large circular trap made of the same material. Thus a shoal of herring following the shore and striking the fence would turn outward and follow it into the net-lined trap. Here they swim round and round until caught in a seine and taken out with dip-nets by the fishermen, who sell and transfer them on the spot to the waiting motor vessels of the buyers. The whole is known as a brush-trap or fish-weir and may be found every few hundred yards along the main shore and numerous islands in and outside of Passamaquoddy Bay. Over a thousand are fished every season



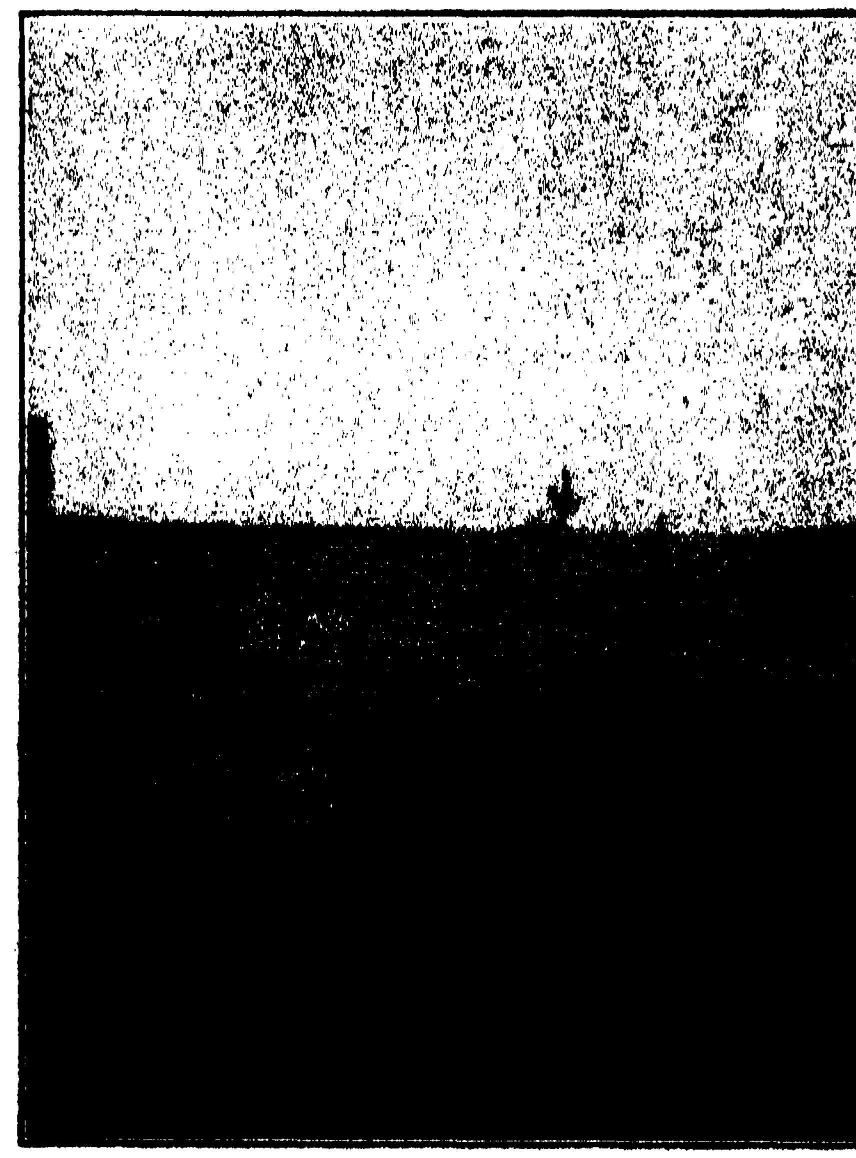
SEINE NET HUNG UP ON LARGE WOODEN WHEEL TO DRY. SUCH SEINE WHEELS REST ON FLOATS, USUALLY WITHIN A FEW YARDS OF THE FISH TRAP.

under license from the government, and the catches of herring have to the fishermen alone a value of $750,000 a year, and to this must be added the gross profits of the canning factories and the value of the haddock and pollack fisheries and smoked fish factories.

Such is the present position, but the fate of the fisheries of Passamaquoddy and adjacent waters will probably be settled during the next few months.

The tremendous inrush and outrush of water between the islands that is primarily responsible for the abundance of fish also makes possible the utilization of the tidal force and has given rise to what is known as the Passamaquoddy power project. It is proposed by an international company to build dams in such a way that two immense basins will be formed. By linking with dams and sluice gates the New Brunswick mainland and three islands with Moose Island, on which stands Eastport, and joining the latter to the mainland of Maine, Passamaquoddy Bay will be closed and all ships have to enter and leave through locks. It is proposed to keep this basin of one hundred square miles at high-tide level. A second basin to be maintained at low-tide level would be formed by damming from Eastport across Cobscook Bay to the mainland to the south (see map), so that there would be a head of water available to pass through the turbines of about twenty feet, and of an unlimited volume.

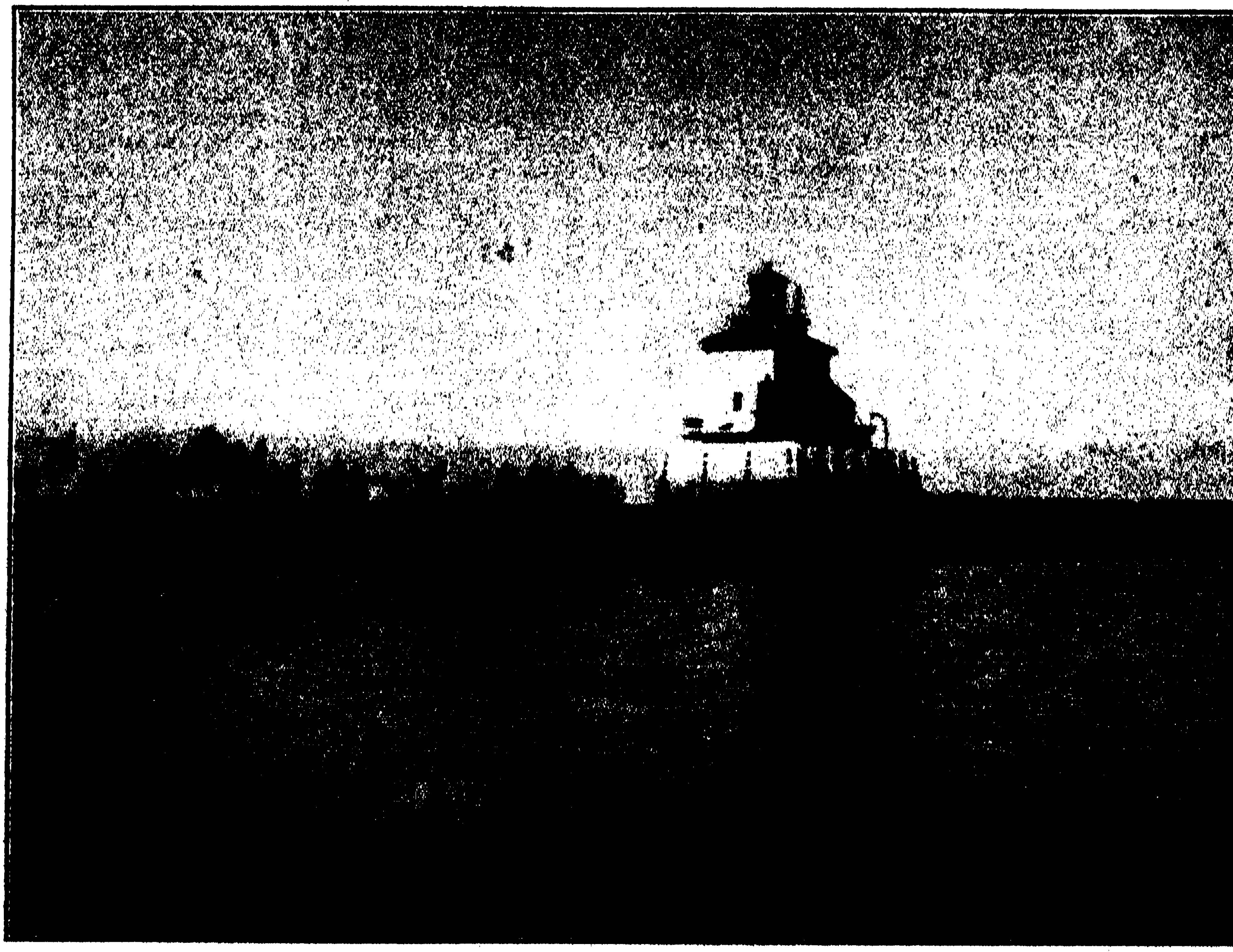
Completed successfully, the project would be one of the greatest engineering feats in the world, but while it is the first of its kind and therefore of an experimental nature, certain results to the neighboring districts are predictable, as is shown from the following extracts from the evidence of Dr. A. G. Huntsman, director of the Biological Station, St. Andrews, N. B. The strong currents and boilings at the entrance to



View up the St. Croix River from the Atlantic Biological Station at St. Andrews, within Passamaquoddy Bay, showing in the distance the site of De Monts' settlement on Doucet Island (marked with an arrow), and in the foreground the fisheries investigation motor vessel, *M. S. Prince*.

Passamaquoddy Bay will be abolished, the rise and fall of the tide within the bay reduced to about five feet and the production of fish food in the region generally very considerably reduced. The sardine, cod, haddock and clam fisheries within the bay will be wiped out, as also the sardine fishery along the whole coast. The surface water will be warmer in summer and colder in winter, and the effect will extend to Nova Scotia and down the coast of Maine, while air temperatures will be similarly affected but over longer distances. Passamaquoddy Bay and the St. Croix River will freeze solid for months every winter and there will be much more ice around the Bay of Fundy.

Thus the power project, if completed, may have an injurious influence on the surrounding district apart from the



WOODEN LIGHTHOUSE, TYPICAL OF THE PASSAMAQUODDY DISTRICT, SHOWING THE PART OF A STAKE FENCE LEADING TO A FISH TRAP.

probable extinction of the New Brunswick and Maine fisheries of that region. On the other hand, as an engineering project, it would be the most ambitious of its kind ever attempted, and also, since there is already a marine biological station within the affected area, it would form an experiment in general marine biology of spectacular size and great importance.

THE PROGRESS OF SCIENCE

THE THIRTEENTH INTERNATIONAL PHYSIOLOGICAL CONGRESS, BOSTON, AUGUST 19–23, 1929

THE Thirteenth International Physiological Congress, which will be held at the Harvard Medical School this summer under the presidency of William H. Howell, of the Johns Hopkins University, brings to mind other similar gatherings. Of historical interest is the fact that four years after the foundation of the British Physiological Society it issued invitations to foreign physiologists to become their guests at the meeting of the International Medical Congress held in London in August, 1881. The desire was expressed to "intensify by social intercourse the social feeling which already exists between foreign and English physiologists." Among those responding to this invitation was Henry P. Bowditch. Six years later, in 1887, the secretary of the Physiological Society was instructed to put himself in communication with the professor of physiology at Bern, with a view of instituting an international meeting of physiologists in that town during the summer session. The outcome of this suggestion was the holding of the First International Physiological Congress at Basel in 1889, which was attended by 124 physiologists from thirteen different countries. The part taken by Sir Michael Foster in organizing the congress was recognized by the Fifth International Physiological Congress (Turin, 1901) by making him honorary president in perpetuity. The original invitation issued from the Physiological Society began, "It is suggested that International Meetings of Physiologists be held at intervals with the object of promoting the progress of physiology by the interchange of ideas and mutual friendly criticism and of affording opportunities to workers in our science of knowing each other personally." In a private letter to Kronecker, Foster wrote, "We ought to do our best to make it as informal as possible so that we may freely and without reserve exchange opinions."

Except during the disturbance of the war years these congresses have been held triennially as follows: 1889, Basel; 1892, Lüttich; 1895, Bern; 1898, Cambridge; 1901, Turin; 1904, Brussels; 1907, Heidelberg; 1910, Vienna; 1913, Groningen; 1920, Paris; 1923, Edinburgh; 1926, Stockholm.

The meeting at Paris was distinctly designated "A Physiological Congress," and many missed the presence of the Germans. At Edinburgh, in 1923, met the first scientific congress held after the war which embraced in its membership men of all countries. Into homes frequently filled with war-time grief, German physiologists were received and made welcome. It made for the healing of the wounds of both nations. When Kossel and when Rubner appeared at different times and places in the program, each was greeted with applause which lasted two or three minutes. Only Charles Richet and Pavlov were received with equal warmth. Kossel and Hans Meyer were the guests of the president of the congress, Sir Edward Sharpey-Schafer, who is to-day the sole surviving member of the original group which founded the British Physiological Society and is one of those who acted on behalf of that society to found the First International Physiological Congress.

A photograph made by A. B. Macallum of Kossel and Schafer standing together before the doorway of Schafer's home at North Berwick, Scotland, presents these two outstanding representatives of their respective countries at the time of the

DR. WILLIAM HENRY HOWELL
PRESIDENT OF THE THIRTEENTH INTERNATIONAL PHYSIOLOGICAL CONGRESS.

PROFESSOR SIR EDWARD A. SHARPEY-SCHAFER AND PROFESSOR ALBRECHT KOSSEL

THE NEW HALL ON THE PARKWAY

congress at Edinburgh. Kossel as a young man had attended the meeting at Cambridge (1898). Twenty-five years later he heard himself enthusiastically acclaimed in Britain and on his return to Germany he told a friend how much it had meant to him.

The Twelfth International Congress at Stockholm was royally entertained by that city with a degree of splendor that the six hundred physiologists who were in attendance will never forget. It is probable that more than four hundred foreign physiologists will cross the ocean to attend the congress in Boston this summer. This offers to the United States opportunities to extend hospitality to these visitors which, in a way, may be commensurate with the kindness and friendship shown in the past to American scientists abroad.

GRAHAM LUSK

A NEW CULTURAL CENTER

THE American Philosophical Society, progenitor of all learned societies in the New World, enters upon the third century of its service to man and science with the most ambitious program in its history. That program, as announced at the general meeting of the society held in April, envisions the erection on the Philadelphia Parkway of an adequate building destined to become a cultural center for the inspiration and guidance of "mankind advancing."

As long ago as 1727 Benjamin Franklin, just come of age, recognized the need in America of a force for intellectual leadership. And so, his autobiography tells us, he formed in Philadelphia from among a majority of the well-informed persons of his acquaintance the Junto which later became the Americal Philosophical Society.

At first the Junto was limited in membership to twelve, but it was not long before Franklin and his friends realized that "virtuosi or ingenious men residing in the several colonies" should be drawn to Philadelphia for meetings and should "maintain constant correspondence." In his call for leaders, dated May 14, 1743, he wrote:

> The first drudgery of settling new colonies, which confines the people to mere necessaries, is now pretty well over and there are many in every province in circumstances that set them at ease and afford leisure to cultivate the finer arts and improve the common stock of knowledge.

Even Franklin, with all his vision and enthusiasm for the growing colonies, could not have predicted the results of that call. From seeds planted by many of the men who answered that appeal for intellectual progress a great nation has risen.

Prosperity and power beyond all dreams "afford leisure to cultivate the finer arts and improve the common stock of knowledge." Distinguished men the world over have been and still are members of the learned society which grew out of Franklin's Junto, and a great cultural center has come to be that society's greatest opportunity.

The society is abandoning its hallowed site on Independence Square not without sacrifice. But to hold to its original purpose, "the promotion of useful knowledge," the move is imperative.

Two years ago, at the celebration of its bicentenary, the members of the society, crowded for space in the old hall, were impressed with renewed force that a new building was an imperative need. A new cultural center was essential for large meetings, for administration and publication activities and the proper housing of the society's expanding library and priceless collections, for study and research and for authoritative dissemination of news in the fields of learning.

In the shadow of Independence Hall the society's home has stood for more

than 140 years. In its rooms and library are priceless collections of manuscripts, paintings and historical relics. In its research and scientific library are more than eighty thousand volumes; the publications of many learned societies as well as its own *Proceedings* and *Transactions;* 13,800 pieces of Frankliniana; Jefferson's original draft of the Declaration of Independence; the written copy of the laws of Pennsylvania prior to 1700; the field notes of the Lewis and Clark expedition and the minutes of the commissioners delegated to determine the Mason and Dixon line.

All around the society's historic building skyscrapers emphasize the material progress of the great nation which was inspired by the Declaration of Independence, for which members of the society were largely responsible. In the cloistered seclusion of its historic meeting room distinguished leaders of thought have gathered to discuss progress in learning and cultural advancement.

The first four presidents of the society after reorganization of 1768 were Franklin, Rittenhouse, Jefferson and Wistar. Fifteen members of the society were signers of the Declaration of Independence; eighteen members were framers of the Constitution of the United States. Nine members of the society have become presidents of the United States and three other presidents have become members.

Among the great leaders of the past have been Jefferson, du Pont de Nemours, Rittenhouse, Rush, Rumford, Priestley, Bowditch, Hassler, Fulton, Day, Henry, Asa Gray, the two Agassizs, Langley, Newcomb, Gibbs, Pickering, Leidy, Cope, George Horn, Ryder, Harrison Allen, Jastrow, Walcott. The membership list of to-day is eloquent of the present.

In the society's meeting room, seated in Franklin's library chair, each president of the society has conducted the stated meetings. On the wall is a portrait of George Washington, by the immortal Gilbert Stuart, and nearby ticks the Rittenhouse clock, used to record the transit of Venus, June 3, 1769. Franklin's battery, his first electrical machine, and portraits of distinguished men, many of them past presidents of the society, are a constant inspiration to the present members at their gatherings.

And a constant reminder that in a flash this treasure house of knowledge and historical record would be lost to mankind!

A spark, a puff of wind, and two centuries of history and contributions to human knowledge would be smouldering embers.

When housed permanently and safely in a modern structure, designed especially to meet the needs of the times, the society feels that an enlarged and progressive program will be possible of accomplishment.

Since the bicentenary, the society has taken important steps toward the achievement of its plan for a new Philosophical Hall. On Philadelphia's Parkway, within sight of the Museum of Art, the Free Library and other such institutions that are vital to cultural progress, the city has set aside a site to be exchanged at the option of the society for its present location. And upon this property, which six years ago cost the city more than a million dollars, it is planned to erect a million-dollar structure.

To this building, designed by Paul Philippe Cret, noted architect and member of the society, will be moved scientific and historical possessions valued at more than two million dollars, including the society's library, much of which now has to be stored in the vaults of a trust company, and is, therefore, inaccessible.

The vision that was Franklin's, when he founded the society, and his leadership, energy and his own contribution, when he helped to make possible the present hall, promise finally to result in

M. HENRI BERGSON

THE DISTINGUISHED FRENCH PHILOSOPHER AND MAN OF LETTERS TO WHOM HAS BEEN AWARDED THE 1927 NOBEL PRIZE IN LITERATURE.

a permanent monument to him and to those who have come after.

The new building is planned not as a monument in stone, however, but as a living memorial to the men who have cleared the frontiers of knowledge in the march of civilization.

Possibilities for greater circulation of new knowledge are of special interest to members of the society. In Franklin's day, weeks and months passed before information could be made available. In these days of telephone, telegraph, high-speed press, air-mail and radio, opportunities for dissemination of information are becoming unlimited. Communication problems have been solved and cooperation with other learned groups is no longer difficult.

To effect a publication and a communication program of world-wide service, the society is enlisting the interest and cooperation of its four hundred American and fifty foreign members. In the new building, under the guidance of a salaried editor, preferably a member of the society, a staff will be employed to effect prompt publication of news of the sciences and humanistic developments, not alone through the present mediums of the society, the *Proceedings* and *Transactions*, but through the establishment of a knowledge bureau, from which research workers, newspaper and magazine editors, lecturers, radio speakers and others may obtain first-hand facts.

This knowledge bureau, members of the society feel, should be of vast service the mankind advancing.

The new building, in addition to the transplanted meeting room, also will provide more adequate opportunity for gatherings to which the public may be invited. Annual meetings in the new hall, with its several rooms for open sessions, should increase in importance each year and the monthly meetings, with more room for non-members, should attract a larger public.

The library, with reading and research rooms nearby, has been designed to make accessible more than five hundred thousand volumes, and the galleries for the society's scientific and historical collections will provide for displays attractive to the public.

In fact, provision is made in the new building for a continually enlarging program of development.

FRANCIS X. DERCUM,
President, American Philosophical Society

A NEW METHOD OF MEASURING REACTION-TIME AND A NEW USE FOR IT IN THE INDUSTRIAL MUSEUM

THE Museums of the Peaceful Arts, New York City, has recently installed a self-operating exhibit whereby the visitor can measure his own reaction-time. In view of the interest manifested in this exhibit, it is believed that a short description and discussion might be of interest.

The fundamentals of the method are quite elementary. For a constant voltage in a circuit containing a galvanometer and resistances the ballistic deflection of the galvanometer is proportional to the time during which the circuit is closed. By using a double contact key, which the visitor operates with his finger, one of the contacts closes an electrical circuit of 60 volts through the tip of the operator's finger. At the same time that this contact is made, the current begins to flow through the galvanometer and continues to flow until the operator removes his finger. The swing of the galvanometer needle as indicated on the ground glass scale indicates the reaction-time in hundredths of a second. A diagram of the electrical connection is shown in Figure II.

It may be of some interest to know that the swing of ballistic galvanometer measures the time limits between the feeling of the electric current in the fingers and the time when the operator breaks the contact by removing his finger. It is quite properly understood that the ballistic swing of a moving coil galvanometer is proportional to the quantity of electricity that flows through it, provided that the period of flow is very short in comparison with the period of the galvanometer. Any galvanometer having a period of more than one half of a second is quite satisfactory for this demonstration.

It is equally well known that the quantity of electricity that flows in a circuit is proportional to the flow of potential multiplied by the duration of the current, thus it is found that the ballistic swing of the galvanometer is a direct measure of the duration of the contact after the operator feels the electrical shock and is consequently a measure of his reaction-time under these particular conditions.

The author used this method a great many years ago for measuring short intervals of time, and it was afterwards adopted by others. However, with the basic knowledge of the principle involved, the Leeds and Northrup Company, Philadelphia, designed and built the present equipment which is being shown at the museum, as may be seen in Figure II. While this obviously seems to consist only of double contact-key resistances, standard cell, and the D'Arsenal galvanometer, nevertheless the design did require considerable thought. For example, it was necessary to find means of determining that the double contact key made the two contacts simultaneously. Also, it was necessary to collaborate the scale in terms of time rather than in terms of quantity of electricity. This time could have been calculated

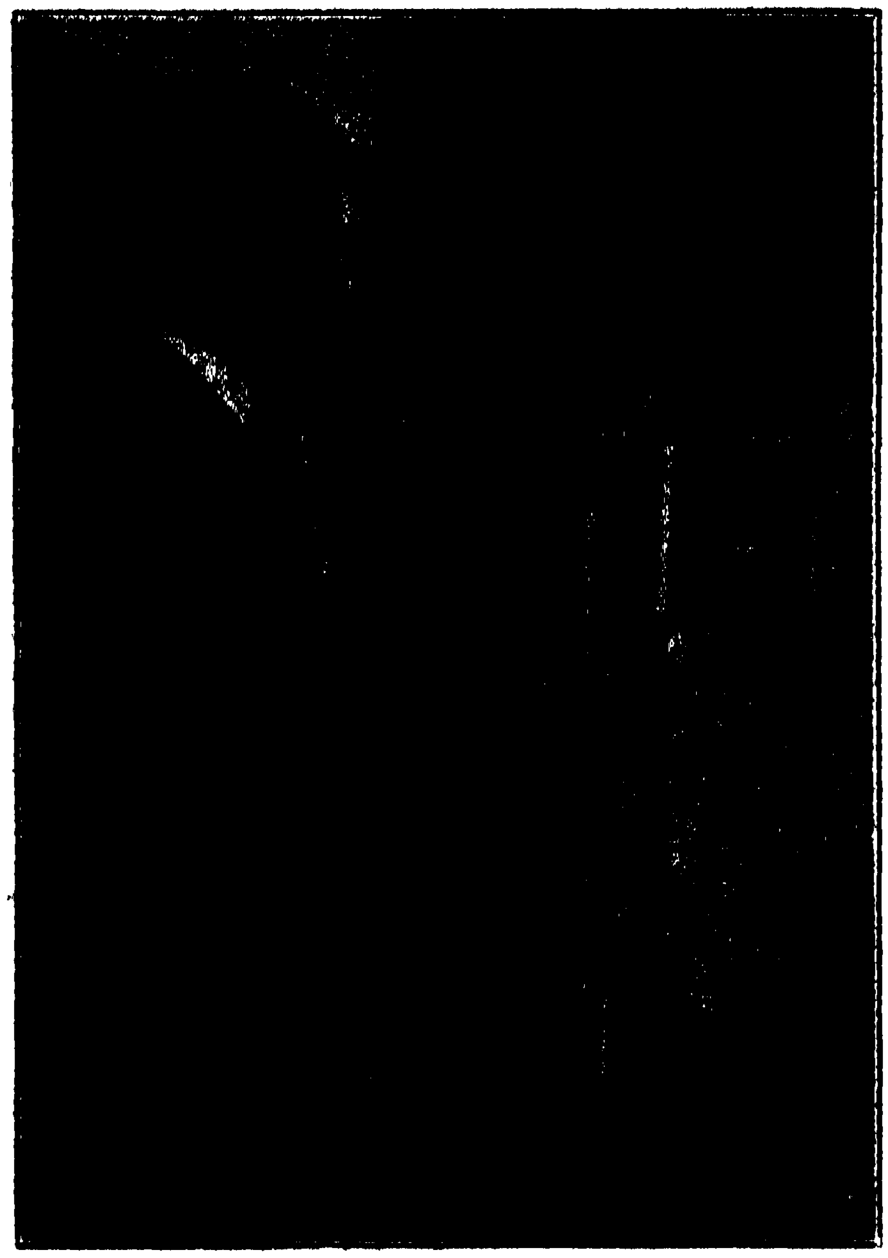


FIG. I. THE REACTION-TIME APPARATUS

arbitrarily from the electrical units, but it was easier to make the calculation by direct comparison with the Leeds and Northrup standard time equipment.

It is also quite novel to use the standard cell for general service in this way. If the current flow is very small, we believe the Standard West cell is altogether the most suitable.

We have found no inclination on the part of any of our visitors to resist unduly in keeping the current flowing. As a matter of fact, even if the visitor does not read instructions, but merely sees the key and presses it, he is quite likely to measure his reaction-time correctly. The electrical current in the finger is just sufficiently annoying and enough of a surprise to him that the visitor is quite certain to react.

As the exhibit stands at the present time, there are some features that are commendable, and some that perhaps might well be changed. For example, if

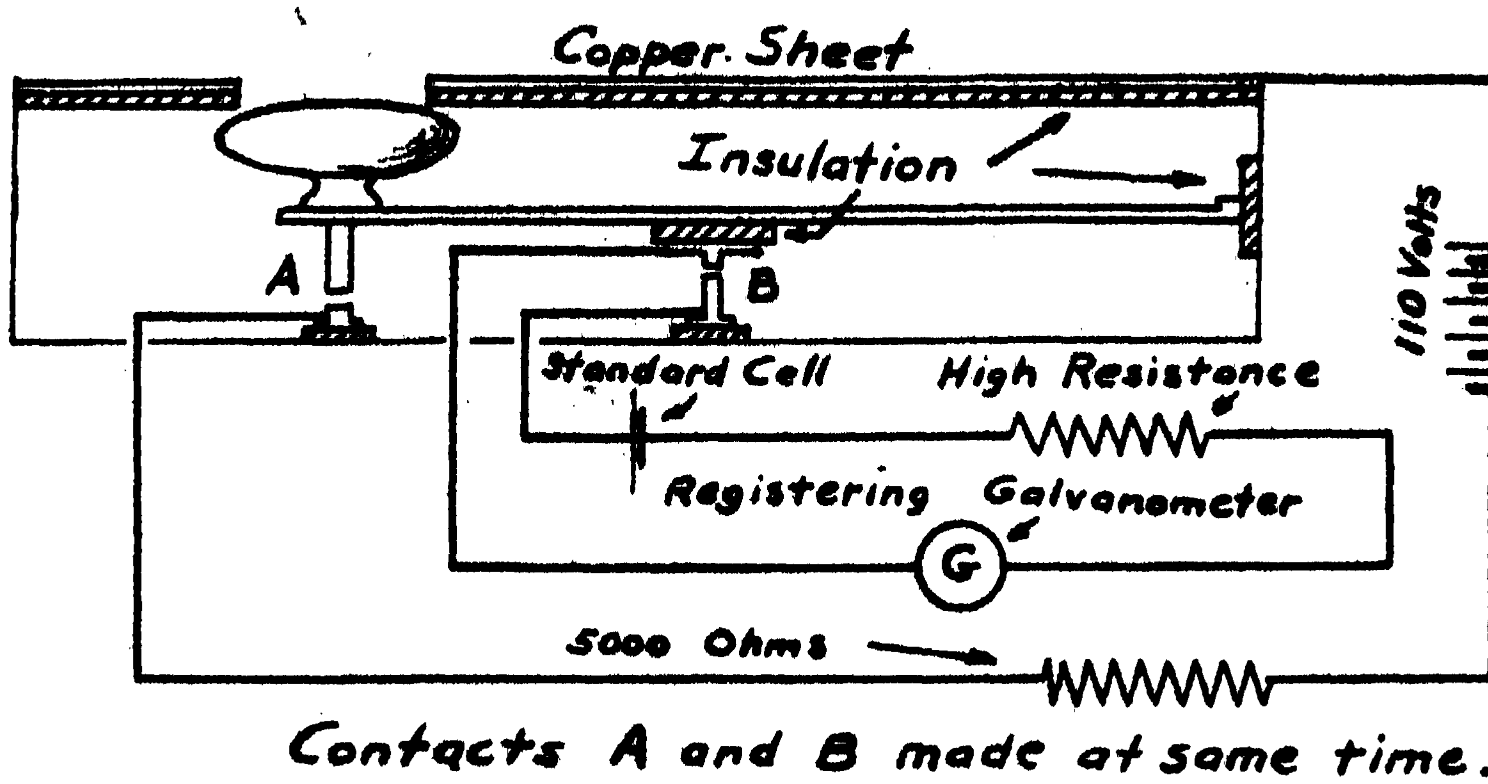


FIG. II. DIAGRAM OF ELECTRICAL CONNECTIONS

we take the first reading of each visitor we find we get values ranging from eight hundredths of a second to as high as thirty-five hundredths, with a preponderance of values in the neighborhood of eighteen hundredths of a second. If, however, the visitor takes a number of readings, the reaction-time measures something different, and is usually of a smaller magnitude. However, in some cases the first value of the reaction-time is smallest, and all the succeeding values are high. We do not have data, however, to justify making any deduction. At least, I do not wish to hazard a conflict with the psychologists.

F. C. Brown,
Director

INDEX

NAMES OF CONTRIBUTORS ARE PRINTED IN SMALL CAPITALS

Date of issue.	Date of issue.	Date of issue.